NOMINATION FOR AN

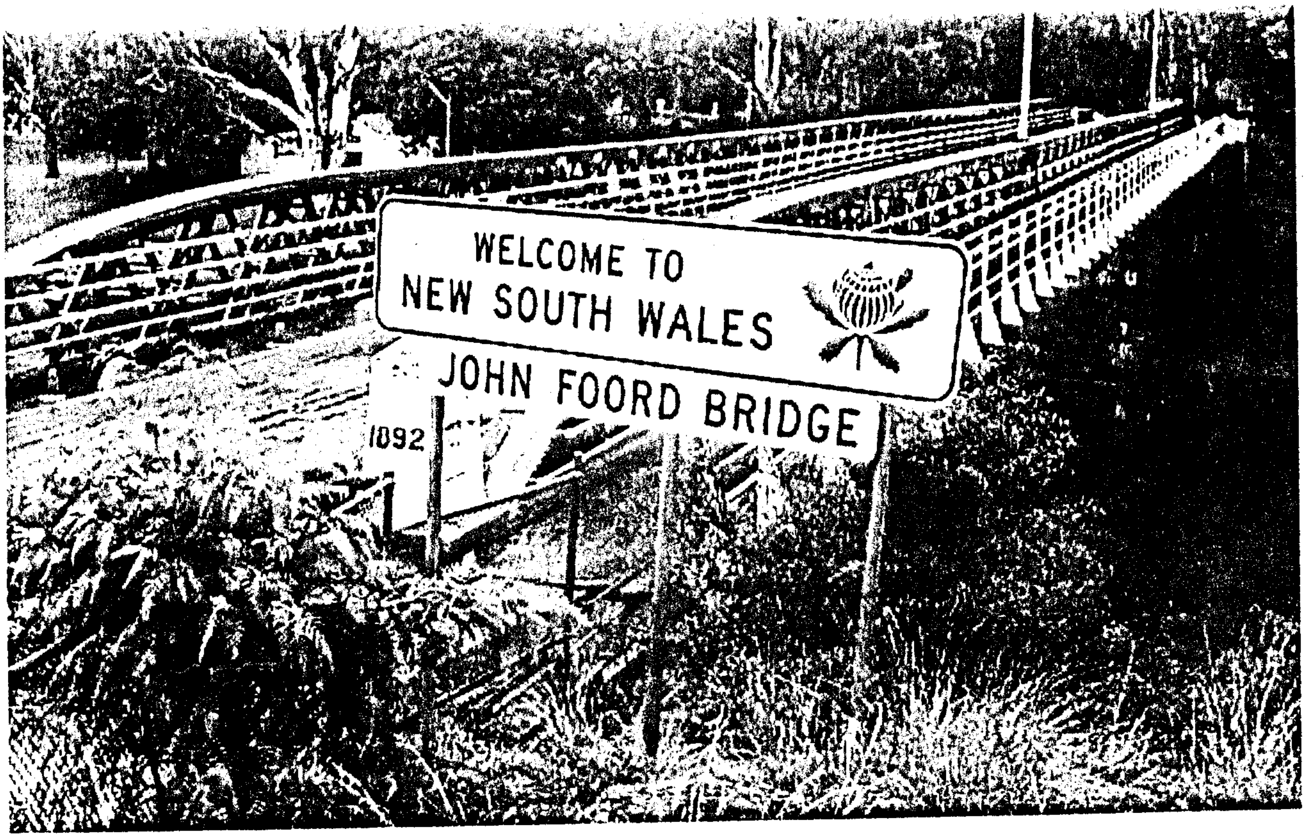
HISTORIC ENGINEERING MARKER

OF

THE JOHN FOORD BRIDGE

over

THE RIVER MURRAY AT COROWA



Prepared for the
Engineering Heritage Committee
Sydney Division, I E Aust
by
Donald J Fraser
August 2000

CONTENTS

STATEMENT OF SIGNIFICANCE

SUMMARY

The 1892 John Foord Bridge at Corowa with its lattice iron trusses and timber approach viaduct on the northern end is a fine example of the type of major road bridge that was dominant in New South Wales in the last quarter of the last century. There were 27 lattice road bridges built between 1873 and 1893 of which 18 survive, some with iron approach spans. The Hunter River is fortunate to have four but the one at Corowa is the only example along the River Murray.

The iron lattice bridge, designed by leading PWD bridge engineer John A McDonald, is among the last group of this type built just prior to the 1894 changeover to American bridge technology and the use of Pratt trusses for metal road bridges.

The bridge has continued a crossing of the River Murray begun in 1862 with the laminated timber arch bridge and has carried local and cross border traffic for 107 years thereby consolidating Corowa as an important rural centre.

The lattice bridge is the visually dominant part of a site that has little changed for over 100 years. The sweep of the river, the trees along the banks, the open land along the Corowa bank and the colonial buildings on the high Wahgunyah side form a heritage environment that is largely untouched.

The Roads and Traffic Authority is to be commended for its decision to retain the bridge and for devising a rehabilitation programme that is a reasonable balance between upgrading the bridge and maintaining its important heritage features.

OTHER ITEMS OF SIGNIFICANCE

The John Foord Bridge is a fine example of a late colonial bridge of the British lattice truss type resting on concrete filled iron cylindrical piers.

The pairs of iron cylinders, cast iron rings until above water then riveted wrought iron curved plates, are braced together by riveted plates pierced by an elliptical cut-out, a simple yet visually pleasing effect.

It is the only bridge of its type in the group of 17 road bridges over the River Murray between Albury and the South Australian border and is arguably the most attractive of the group, so much so that a photograph of it appeared on the cover of the 1997 District Telephone Directory.

It is one of 18 surviving iron lattice bridges in New South Wales which were the dominant group of iron road bridges built from 1873 to 1893. They and the timber trusses were the most significant road bridges in colonial New South Wales.

The 3 span continuous design of the John Foord Bridge is an example of the sophistication in structural analysis being practised by engineers of the Public Works Department in the last quarter of the colonial period.

It is the only 3 span lattice bridge with spans of 113, 140, 113 feet, exceeded only by the 140, 182, 140 feet spans at Aberdeen and Elderslie, both over the Hunter River.

John A McDonald, its designer, was the leading bridge engineer in the Public Works Department, at the time, and whose design for timber truss road bridges in 1884 now bears his name.

When completed in late 1892 the bridge at Corowa was one of only four bridges over the River Murray (Albury, Corowa, Mulwala and Echuca) so it had a significant impact on inter colonial commerce and communication.

The bridge was featured in promotion material about Corowa as the venue for the 1893 Federation Conference.

The timber approach spans are a standard form of construction of which there are many in the District and hundreds in service in New South Wales. The spans at Corowa have been modified since 1892; a second layer of deck planks, laid longitudinally, were added soon after 1901 and the timber girders have been propped at their mid spans by intermediate trestles since 1931. All the original timber components have been renewed at some time during the past 100 years.

Consequently, the northern approach spans are, in themselves, not significant structurally or in heritage terms. They are in fact the weak link in the crossing. But they are an original part of the fabric of the whole bridge so there is an historical association of timber and iron structures that is of heritage significance.

The John Foord Bridge is the only bridge along the River Murray named after a pioneer settler.

Commemorative Plaque Nomination Form

Date....... September 2000

To:
Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
Engineering House
11 National Circuit
BARTON ACT 2600

From:
Engineering Heritage
Committee
Sydney Division

The following work is nominated for a :-

~~National Engineering Landmark~~

Historic Engineering Marker.

Name of work .... The John Foord Bridge, 1892 lattice road bridge

Location .... Murray River at Corowa

....

Owner .... Roads and Traffic Authority, NSW

....

Owner's response .... RTA has approved the plaquing proposal

....

Access to site .... Bridge still in service for road vehicles and pedestrians

Future care and maintenance of the work .... RTA will continue this work until a new bridge upstream is built, then it will rehabilitate J F Br then Shire Council control.

Name of sponsor .... Nil

Don Cottee ....

Chairperson of nominating committee

ADDITIONAL SUPPORTING INFORMATION

Name of work .... John Foord Bridge at Corowa

Year of construction or manufacture 1892

Period of operation ....1892 and to continue

Physical condition .... Good, and to be rehabilitated

Engineering Heritage Significance :-

Technical, scientific value .... Good example of a British iron lattice bridge

Historical value .... Oldest road bridge over the Murray River

Social value .... Colonial customs post, Federation town

Landscape or township value .... Charming river setting and gateway to Corowa

Rarity .... Nil

Representativeness .... Good example of its class of bridge

Contribution to nation or region .... Important colonial link with Victoria, Federation

Contribution to engineering .... Member of significant group of lattice bridge

Persons associated with the work .... John A McDonald, Bridge Engr, PWD, NSW

Integrity .... Retains its original fabric

Authenticity .... Its the original 1892 bridge

Comparable works (a) in Australia .... Another 17 in NSW, a few in Victoria

(b) overseas .... Plenty in Britain

Statement of Significance, its location in the documentation .... see Contents

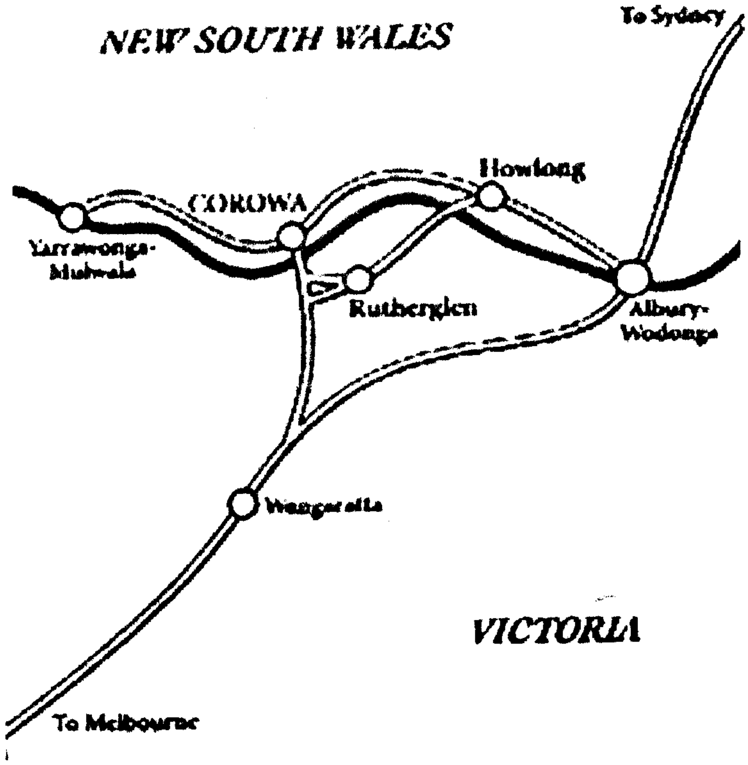
Citation (70 - 80 words optimum) - or refer to location in the documentation ....
see Contents

Attachments to submission (if any) ....

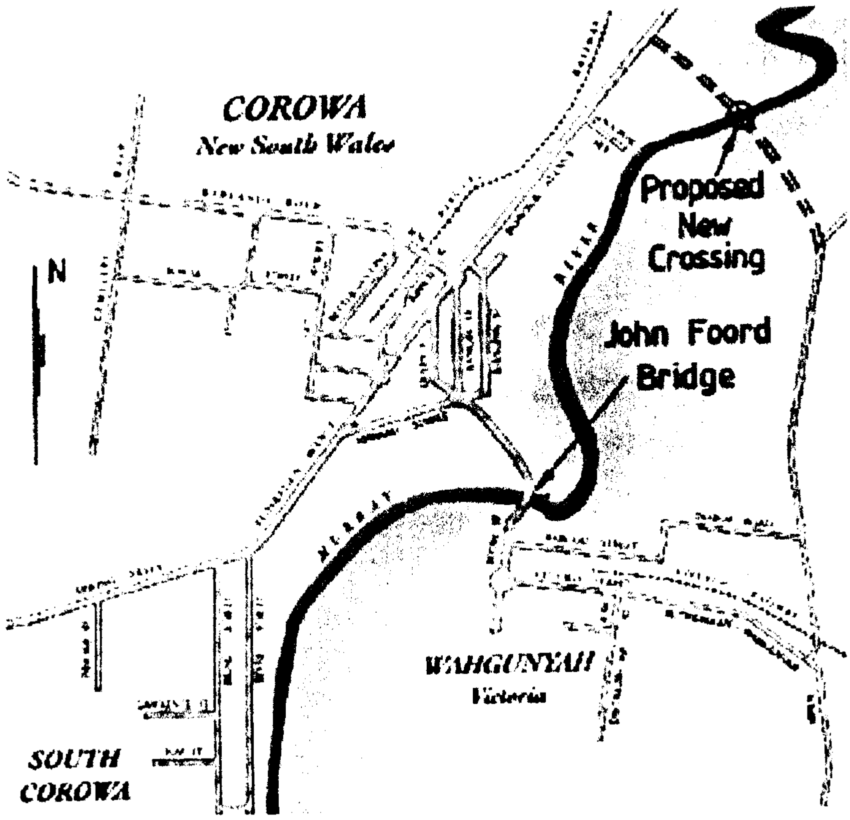
Proposed location of plaque .... Possibly on date plinth at southern end

LOCATION AND THE BRIDGE SITE

Corowa is located on the River Murray 60 km west of Albury.

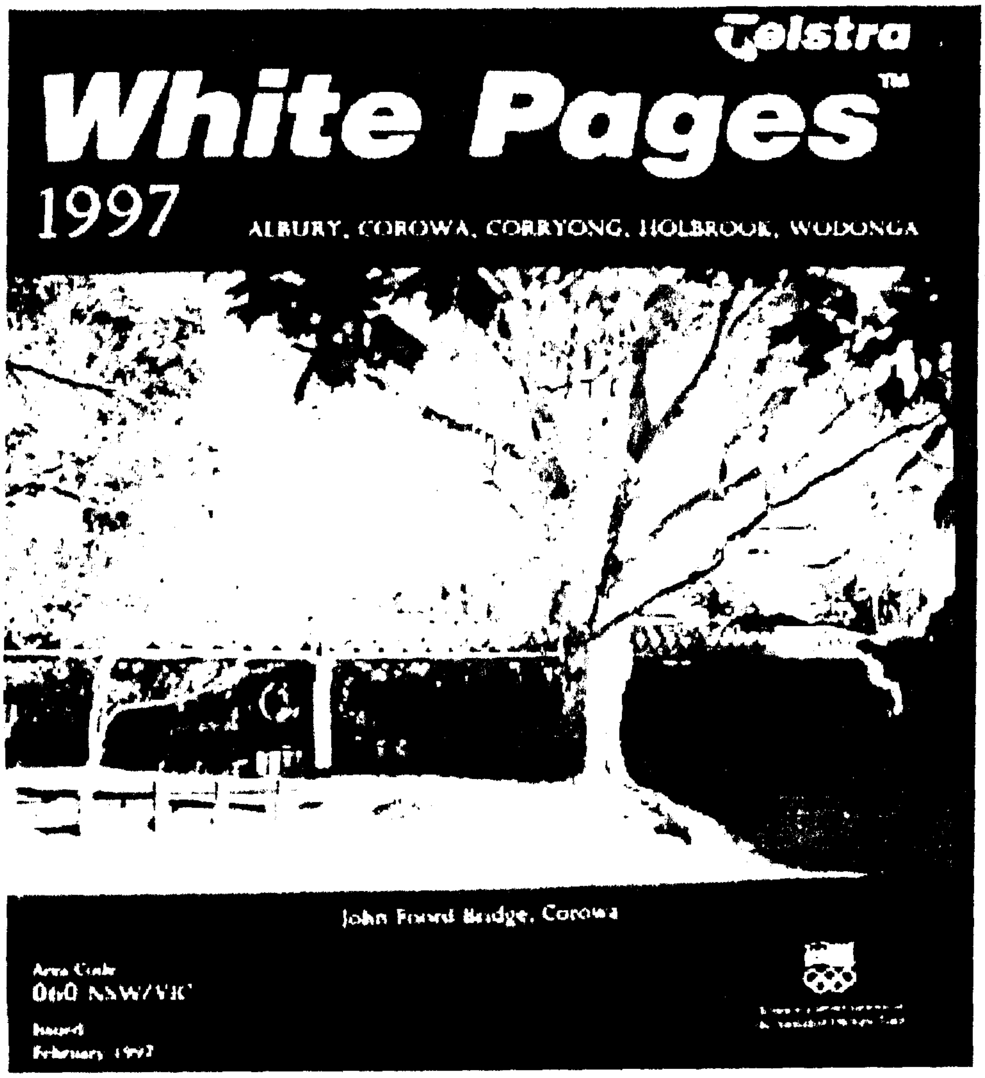


Location map



The bridge site

Although this major inland river generally flows westwards towards South Australia, its meanderings mean that the orientation of its course can be at any degree of the compass. At Corowa, the river flows predominantly North-South with the township in New South Wales on the west side and Wahgunyah in Victoria on the east side. But at the bridge site the river turns East-West, consequently the orientation of the John Foord Bridge is North-South.



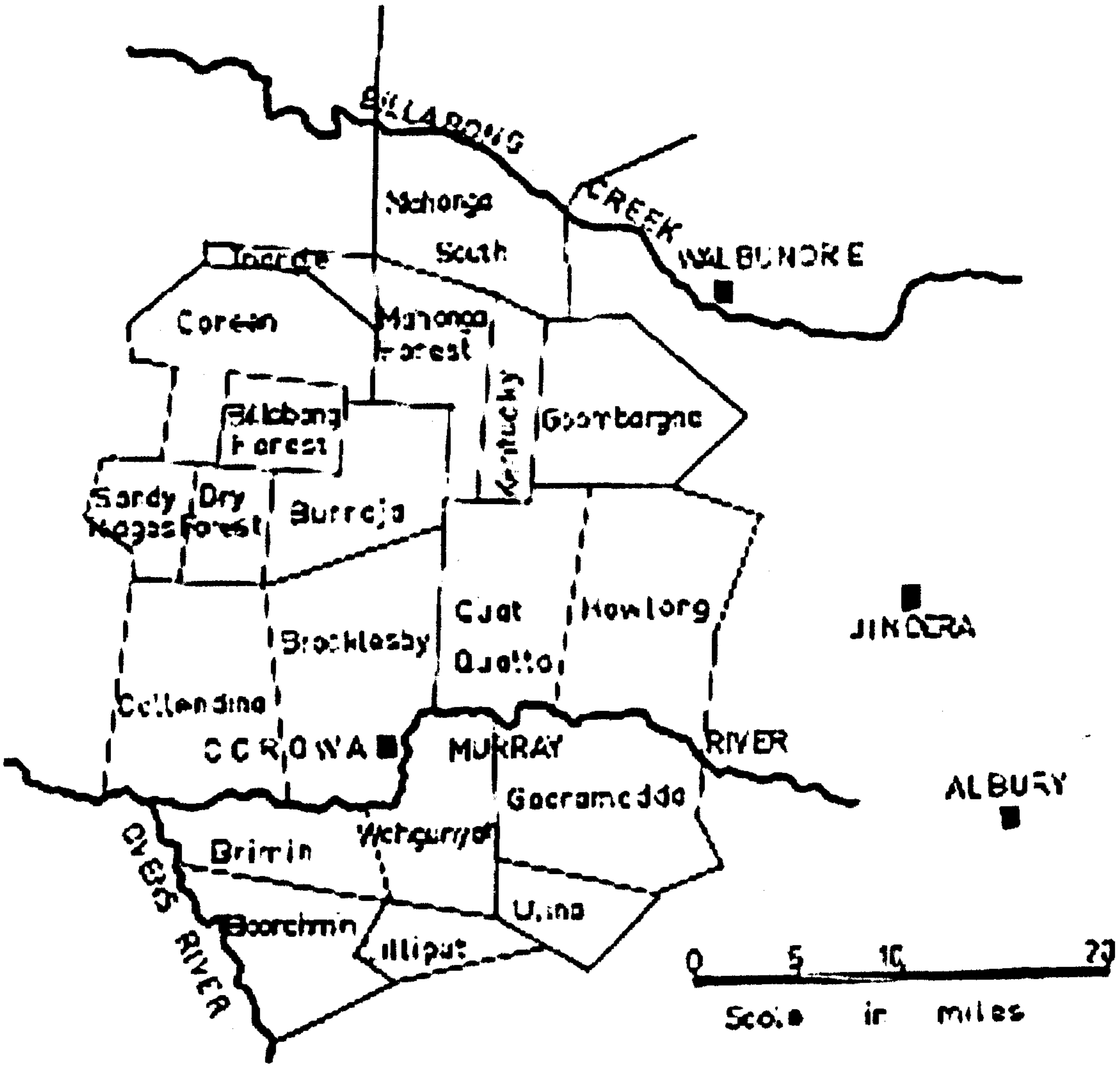
HISTORICAL REVIEW

THE BRIDGE NAME

John Foord

John Foord was born at Brighton, England in 1819 and arrived in Sydney in 1827 with his father, stepmother, sister Ellenor and his aunt's family. The Foords settled in Parramatta where the father went into business as a coach builder. When only 20, John Foord ventured into the unsettled area at the junction of the Ovens and Murray rivers.

In 1839 while overlanding in a north-easterly direction from the Ovens, he and John Crisp traversed the Wahgunyah region which led to them forming the Wahgunyah Cattle Station in 1841, licensed as Reserve No 34 under the 1836 NSW Crown Lands Occupation Act because that southern side of the river was then part of New South Wales.



The squatting runs around Corowa in the 1840s.

Separation of the Colony of Victoria was formally proclaimed on 11 November 1850 and in 1851 John Crisp sold his share to John Foord so his sole-owned run was now in Victoria. He was soon to achieve renown in the district through the coming of the River Trade and gold rush at Rutherglen.

During 1853, paddle steamers steadily worked their way up the River Murray from Goolwa in South Australia thus pioneering an inland transport system that flourished for about 50 years until "killed off" by colonial railways reaching a number of towns on each side of the river. Early in 1854 Francis Cadell reached Wahgunyah with his *Lady Augusta* and the next year he reached Albury in his aptly named *Albury*, 300 km upstream from Goolwa. The impact on northern Victoria as well as southern and western New South Wales was enormous, well beyond the scope of this report.

John Foord was in a good position to capitalise on the benefits of the River Trade because under his preemptive rights as an original lessee he had been able to lay out the private town of

Wahgunyah in 1853, and across the river in New South Wales was North Wahgunyah, soon to become Corowa. The combination of his town, river transport and the Rutherglen gold rush in 1859 increased the population moving into the district, stimulated wheat and wool production and greatly increased the flow of people needing to cross the river.

The commemorative plaque on the John Foord Bridge, Corowa

Consequently, John Foord became town planner and settlement authority, storekeeper and flour miller, transport proprietor (he owned two vessels trading between Albury and Echuca), punt operator and part-time operator, and he joined others to form a private company which sponsored construction of the first bridge across the river.

He was a prosperous and influential man who was well known for his generosity, kindness and honesty both to farmer settlers and the local aborigines, and he remained so to his death on February 15, 1883 aged 64 years. He has been honoured in many ways in the district, particularly on the Victorian side, but none more fitting than to have the 1892 bridge bear his name in 1958, the only bridge along the River Murray named after a pioneer.

COROWA AND WAHGUNYAH - HISTORIC TOWNS

After establishing Wahgunyah, John Foord started the commercial area surrounding present-day Sanger Street, Corowa, which in 1859 was called North Wahgunyah. But an earlier start had begun in 1856 in the area now known as South Corowa when NSW surveyor Parkinson measured lands likely to sell as a town site, followed in May 1858 by a town design prepared by District Surveyor Adams. This plan was officially gazetted on February 4, 1859 and included the description "a town called Corowa situated about 40 miles below Albury, opposite the private town of Wahgunyah, better known as Foord's". On 24 March, 37 suburban and town lots were sold.

But four days earlier on the 20th John Foord had purchased freehold land in North Wahgunyah on the western side of what became the main street of Corowa, Sanger Street. Maybe from experience with his own town of Wahgunyah, he had a better idea of where development would take place. It was closer to his punt and subsequent bridge site, but whatever, his purchase became Corowa rather than the government's Corowa, now South Corowa.

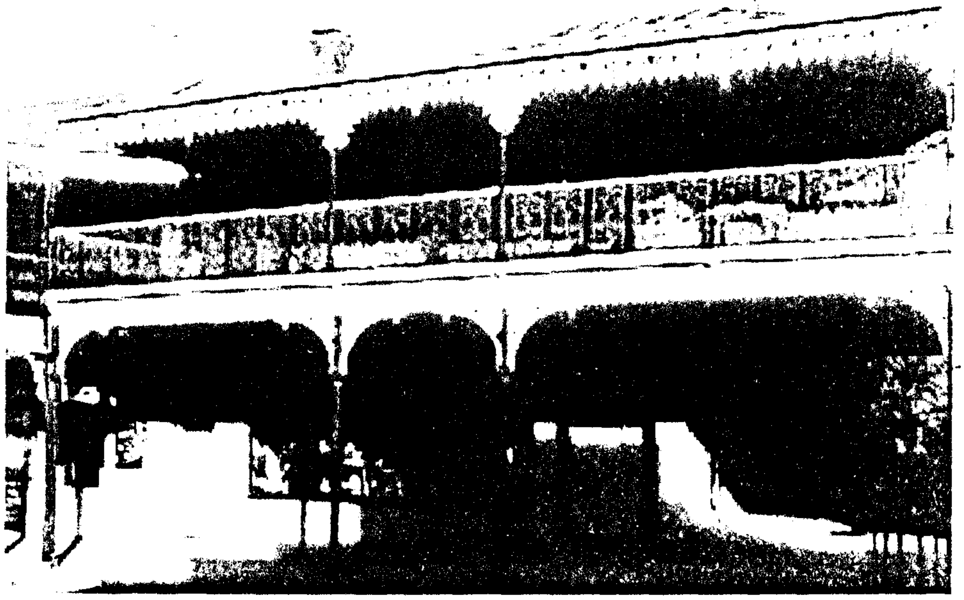
Development was spurred by the Rutherglen - Wahgunyah gold-rush, officially given as July 1860 but often quoted as 1859. However, the rush was short lived, lasting only several months, so many failed diggers settled in Corowa. The boom year of 1861 saw the construction of a Post Office, the Royal and Globe Hotels, many homes and stores, plus the appointment of a Court of Petty Sessions. A significant factor in the retention of settlers was the 1861 Robertson Land Act in New South Wales which encouraged the selection of property and the breaking up of the large squatting runs.

In 1862 the first bridge, a laminated timber arch structure, across the river was completed next to Foord's punt on a reasonably direct line from North Wahgunyah (Corowa) to Wahgunyah which established Corowa, at the expense of Wahgunyah, as the trade and traffic centre. By 1866 North Wahgunyah (Corowa) had a population of 200 whereas the official township at South Corowa was largely unsettled. The emerging Corowa added a Customs House, a bonded store, a Church of England, more general stores, two more hotels, a steamboat booking office, a goods shed and loading docks. The 1871 census listed 244 residents.

At that time Wahgunyah looked like the main centre because it was the 'port' for the river trade, but by 1875 Corowa was fast becoming the major centre. Its future lay with agriculture and land transport, particularly the railway which reached Corowa in 1892, by which time other branch lines on both sides of the river had caused the demise of the River Trade by diverting goods directly to Melbourne and Sydney.

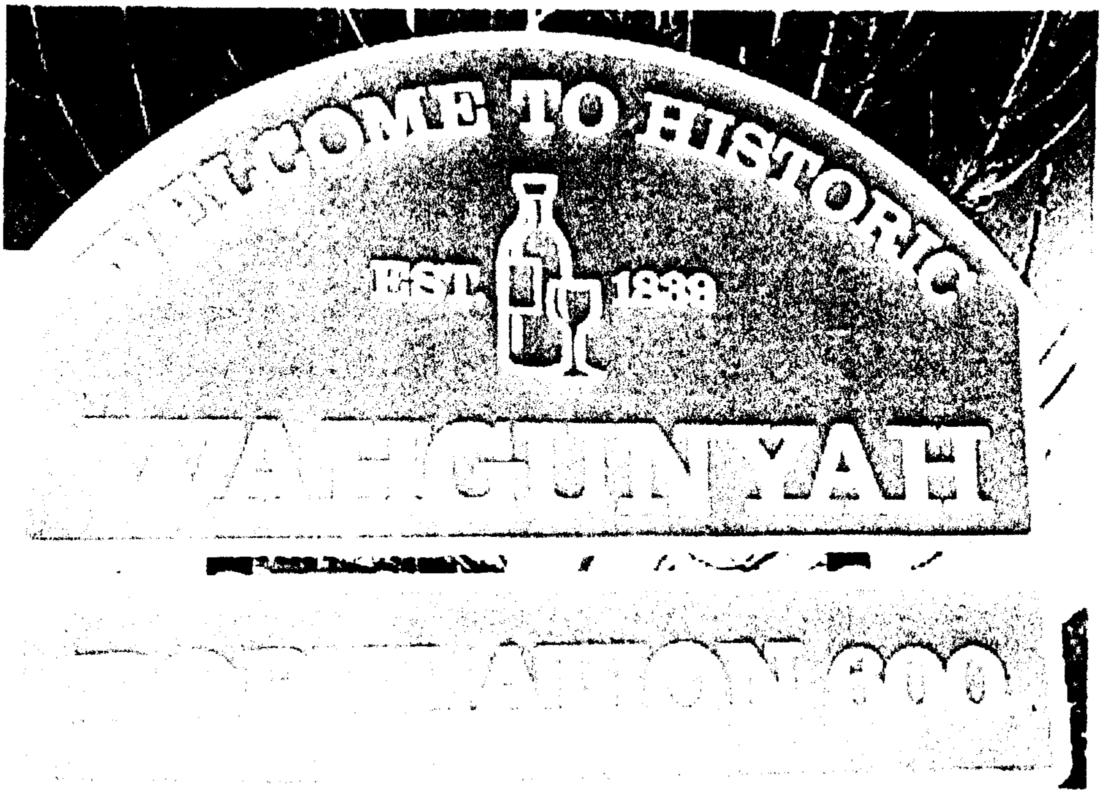
Corowa's township continued to thrive through the 1880s and into the 1890s despite the economic depression. Its position as a major river crossing meant that an expensive imported iron lattice lattice bridge was opened in 1892 alongside the ailing 30-year old timber bridge. Then came its crowning achievement, hosting the 1893 Federation Conference, a significant event in the lead-up to Federation in 1901.

Throughout the twentieth century Corowa steadily developed as an important rural centre, currently the population is around 5200, whereas Wahgunyah's population is only 500. But development has not been at the expense of colonial heritage. Some 23 heritage gems, mostly buildings, survive in Corowa and Wahgunyah from that era, and the Corowa District Historical Society with its Federation Museum actively promotes an awareness of that heritage, such as the centenary celebration for the 1892 bridge.

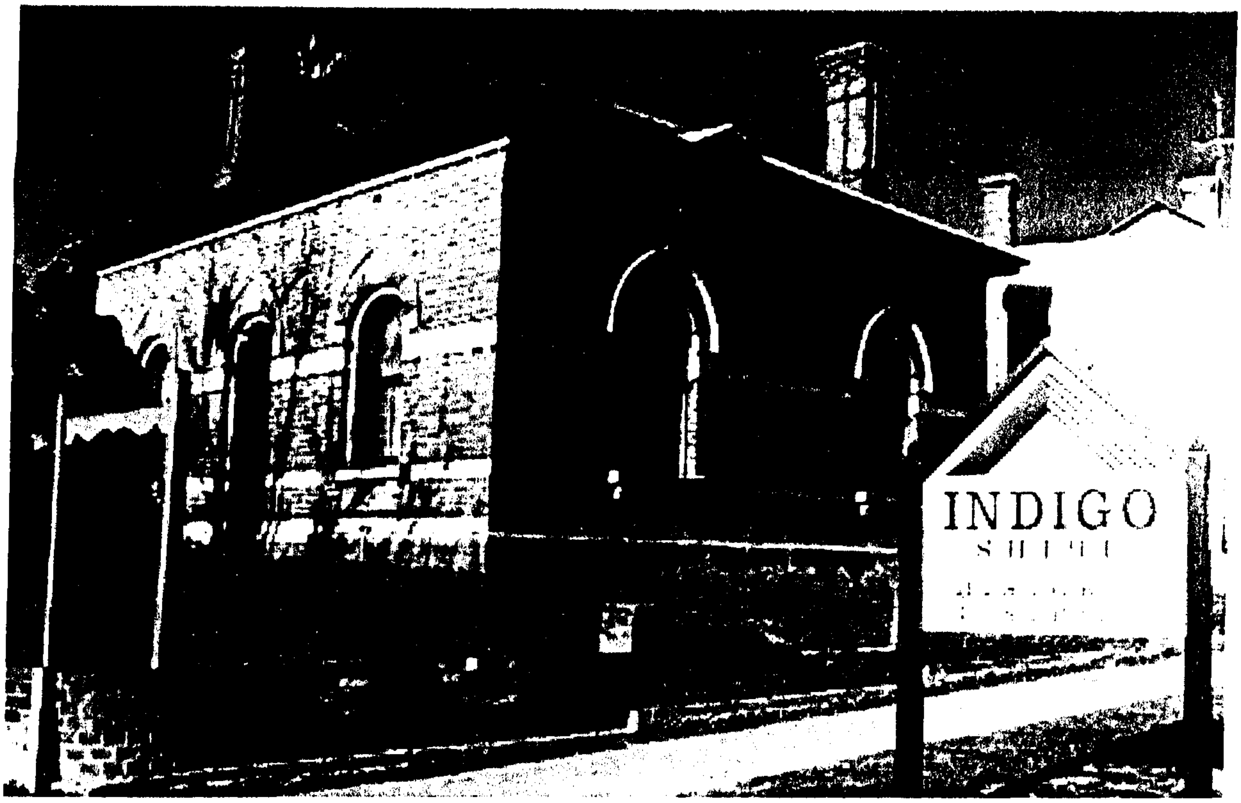


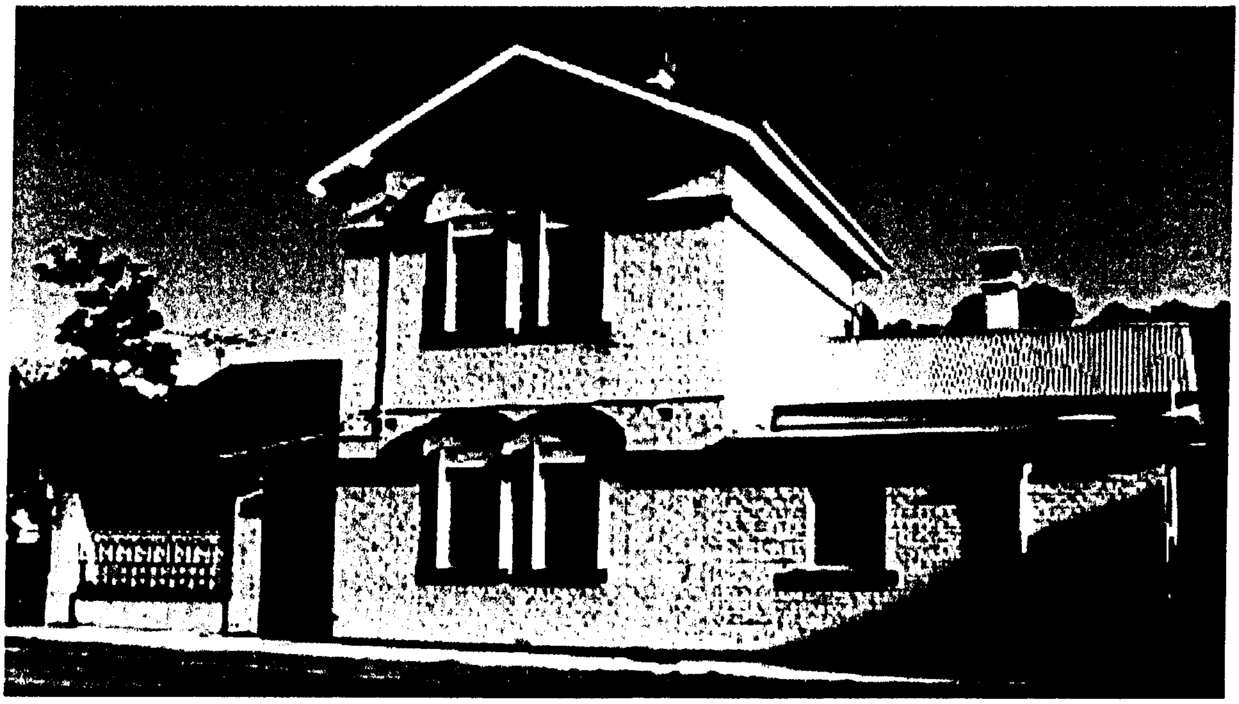
In Corowa, the 1870 Star Hotel and a recycled commercial premises.

In Corowa, the 1886-90 Court House and a Federation era Bank building.



Federation Museum, Corowa, the date refers to the founding of the band,
and the welcoming sign to Wahgunyah on the south side of the river.





In Wahgunyah, the 1880s Customs House and a colonial neighbour.

THE 1862 BRIDGE

In late 1857 or early 1858 John Foord purchased a surplus punt/ferry from John Hopwood at Echuca, where the latter had completed a floating pontoon bridge on the River Murray between Echuca (Vic) and Moama (NSW). Foord towed the punt to Wahgunyah and began operating it, then later leased it.

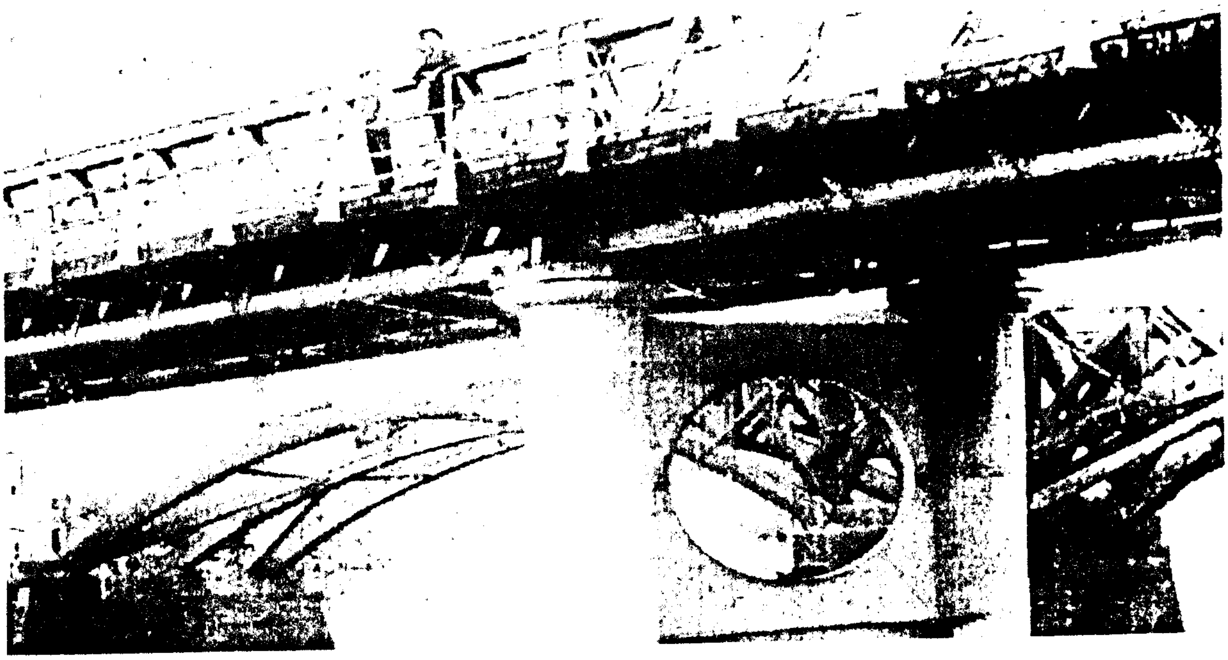
Echuca in the late 1850s with Hopwood's pontoon bridge on the left and the punt.

But it soon became clear that Foord's punt could not meet the demand for carrying goods and people across the river. A bridge was required but the NSW Government could not afford to build it. However, privately built toll-bridges were permitted by the Government as an aid to rural development. In 1859 Foord, Christopher Baldock, Henry Bayliss and other subscribers formed the Wahgunyah Murray River Bridge Company, had plans prepared for a 3-span laminated timber arch bridge to cost 6,000 pounds and lobbied the government in Sydney. The matter was referred to a Select Committee in February 1861 which reported favourably to the Legislative Council on 23rd March. The Wahgunyah Murray River River Bridge Company Bill was passed on the third reading in the Legislative Assembly on 26th March. Eighteen months later the bridge was opened in September 1862 at a completed cost of 10,000 pounds. [To help the reader appreciate the expensive nature of the project and investment at that time, the cost is equivalent to $1 million in 1997. The same index factor of 100 can be applied to the tolls - a person 3 pence ($1.25) - a horse 1 shilling ($5) - a cart or dray of 4 wheels, 4 shillings ($20).] So the convenience of the bridge came at a high price, no wonder there was prolonged agitation to have the tolls removed.

The first Wahgunyah bridge and, left, Foord's ferry.

The Town and Country Journal, based in Sydney, mentioned the bridge from time to time starting in 1870, then in 1883 noted that it was a "substantial work, well-tarred, in fair condition" and concluding in 1895 with "antiquated structure". But the most frequent references occurred in the local Corowa Free Press, typically - June 1878, a public meeting asking the NSW Government to purchase the bridge and declare it free to the public - September 1878, repairs required to the approaches - October 1891, warning of the dangerous condition of the old bridge - June 1892, traffic restricted to one lane and one vehicle to cross at a time, controlled by a flagman at each end of the bridge. The NSW Government did purchase the bridge in 1881 and eliminated the tolls which was celebrated with a sports day and fireworks. It was another decade until a new bridge was built.

Two years after the new 1892 bridge came into service, dismantling the old bridge began. Most of the timber was salvaged and offered for sale in March 1894 on behalf of the Department of Public Works by A. A. Piggin & Co Auctioneers. A piece of of the bridge timber is on display in Corowa's Federation Museum. The piles on the river bank were retained and used for a jetty for many years. The remnants are visible at times of low water, se next page.



Top: The 1862 laminated timber arch bridge was dismantled during 1894 and all useful timber was sold at auction, but the pier piles at the shoreline (Below) were adapted for use as a jetty. That too passed, along with the river trade, and are now only visible at times of low river flows.

THE 1892-93 BRIDGE

By 1889 it was obvious that the old laminated timber arch bridge was deteriorating and would soon become unsafe to use. Repairs would have been expensive and not cost-effective in the long term, so a new bridge was planned.

A lifting span in the middle of the river was not required because river conditions upstream prevented paddle steamers going beyond Wahgunyah. Therefore a sequence of spans was required to cross the 350-foot wide stream, built high enough to clear the maximum flood. The latter could be readily achieved simply by constructing tall piers to the desired height.

However, for the sequence of spans, contemporary technical and financial constraints meant that only two options were feasible - 5 x 90-foot McDonald timber trusses (the 140-foot Allan timber trusses were 10 years off) or 3 x 120-foot iron lattice trusses. There were already about 100 bridge sites with McDonald timber trusses made from North Coast ironbark and about 18 sites with iron lattice trusses made from imported wrought iron.

Factors favouring the iron lattice bridge were; fewer piers (always expensive and slow to build in a river), a clearer waterway for floods and debris to pass, the unsatisfactory experience with deterioration of the old timber arches, and the greater service life to be achieved using an iron bridge. The persistent complaints from the Riverina about neglect from Sydney plus colonial rivalry with Victoria may have had some influence. It was a "hot" political issue that affected successive government policies on infrastructure in the border regions.

In September 1889 boring operations began in order to determine the depth to rock for the proposed concrete-filled iron cylinders, and leading bridge engineer John A McDonald, of the PWD Roads and Bridges Branch, began the design. His calculation book is held by the current Bridge Branch of the Roads and Traffic Authority.

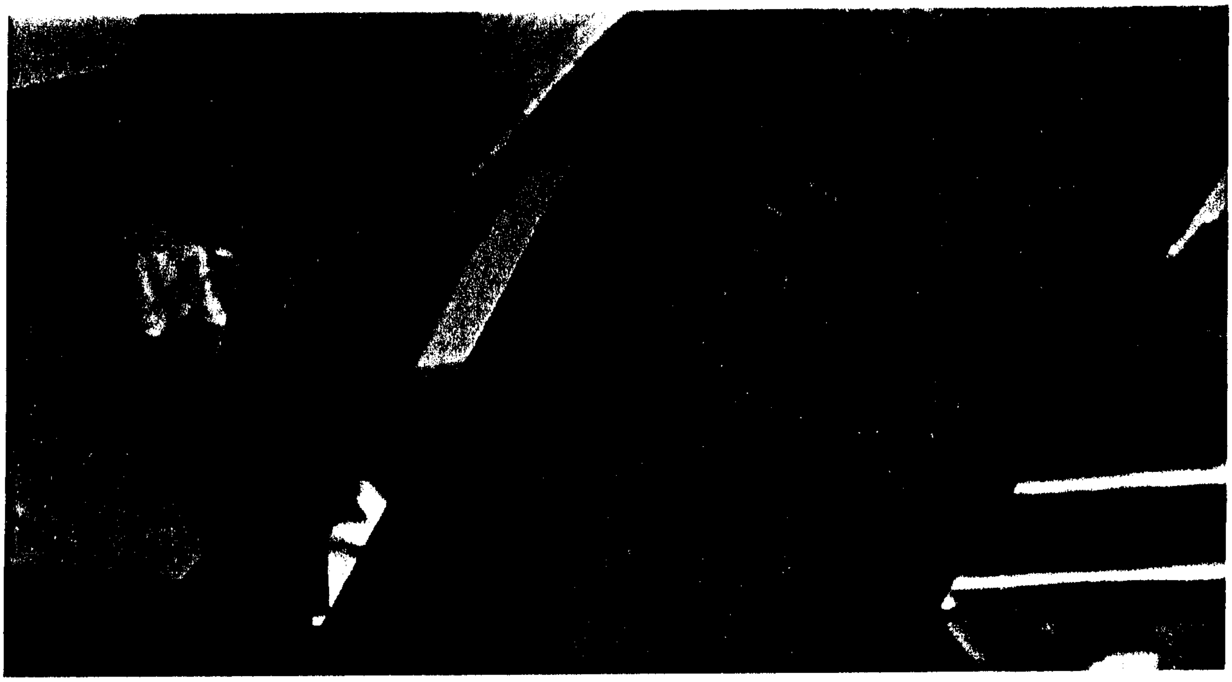
Lattice trusses were chosen because British bridge technology was still dominant and these bridges had already proved themselves to be as safe as, but cheaper than, heavy solid plate web girders such as those at Echuca. Instead of three equal spans McDonald chose spans of 113 feet, 140 feet, 113 feet continuous over the piers so as to form one 366-foot long bridge. The reason for this arrangement of spans was explained in Section 4, the Technical Review. It was a sound proven design.

But the design was immediately criticised, in the Corowa Free Press on 2 October 1891, for having a roadway only 18 feet wide. It was too narrow for loaded wool carts to pass on the bridge and was awkward for a wool cart and a buggy to pass whereas only ordinary light vehicles could pass each other. The article went on to contend that widening the bridge deck to 36 feet would cost "barely a third more". The article ended with a broadside at "engineering objections" and "stubborn officialdom". The agitation persisted through to July 1892 but to no avail. Eighteen feet was the standard deck width on bridges (it remained so until the 1920s) and was a compromise between essential usage, some inconvenience and costs. Design

standards and safety could not be reduced to make the original design wider, because doubling the width meant doubling the load on the bridge, which virtually doubles the materials use and hence doubles the final construction cost. A contributing political factor was that the bridge was a border crossing and the New South Wales and Victorian Governments were bickering over shared costs, particularly any increase to achieve a duplication or a new design for a wider structure. No extra funds were allocated.

The inconvenience of a narrow deck has been a permanent feature of the John Foord bridge and will continue to be after rehabilitation.

In colonial times all iron (and later steel) for metal bridges in New South Wales was imported, mainly from England but also from Belgium. For example, the iron for the 1881 lattice bridge at Muswellbrook was supplied ready for erection from the well known English company BUTTERLY of DERBYSHIRE, and the iron for the bridges at Elderslie (1891) and Aberdeen (1893) bridges was supplied by the Belgian company PROVIDENCE HAUMONT. This situation continued until the 1920s because production from the 1916 BHP steelworks at Newcastle was used for World War I purposes. On the 1892 Corowa bridge there are the rolling marks of the steel makers. On the T-sections of the top and bottom members of the lattice trusses the mark is SHELTON, a British steelmaker, and on the sloping channel sections the mark is BURBACH. Figure 3.13 of these rolling marks is on the next page. This same combination is on the 1895 lattice spans for the lift bridge at Wilcannia.



Rolling marks on the structural iron sections of the lattice trusses.

One of the consequences of importing iron was the delay with shipping. As late as January 1892 the Corowa Free Press reported that the arrival of 140 tons of ironwork was long overdue. Work on the bridge was suspended and in June contractors Downey & Co were relieved of their contract. After a wait of about six months the ironwork arrived on 1 July and work recommenced using PWD day labour. By the end of September the riveted ironwork was complete, the temporary staging removed with only the timber deck to be laid.

At this stage, with a new self-supporting structure high and clear across the river, it was acknowledged that "now it presents a very fine appearance and is a vast improvement on the wooden structure it supersedes".

But criticisms and complaints soon emerged, this time about the timber deck (and have continued to the present day). Although the preferred decking for these lattice bridges was a

tarred macadam surface on metal plates (upturned dish-shaped plates called buckled plates) supported on longitudinal beams carried by the cross-girders, its use was restricted to heavily trafficked bridges. Being a lot more expensive, it was not standard for all such bridges. For bridges deemed to be for minor roads with less frequent traffic (local and seasonal), timber decks were used. This was the situation at Corowa at the time, compounded by the concurrent economic depression, so cost-cutting was the order of the day.

Initially, the single layer of 4 inch thick timber planks would have been laid diagonally (45 degrees) to the longitudinal timber bearers. This is why in the cross-sectional drawing the planks appear with cross-hatching rather than as horizontal rectangles across the bearers. However, experience had shown this arrangement to be unsatisfactory so the planks were actually laid square across the bearers, still only one layer of planks. Although each plank was designed to support a heavy wheel load between bearers, factors such as the variability of natural materials such as timber, the loss of timber due to wear and tear, impact and general weathering, meant that planks would begin to fail before maintenance procedures got around to replacing them.

The John Foord Bridge soon after completion, showing the original cross planking.

As early as 6 January 1893 there was a long letter to the Editor of the Corowa Free Press signed "Old Pioneer" which began

> *Yesterday the Corowa-Wahgunyah Bridge was opened for traffic.*
>
> then went on to say that it was
>
> *on the wrong side of the old one and was about 6 ft too narrow .*
>
> followed by

it reflects great credit upon the designers and those who carried out the work.

but (and here's a prophetic statement)

there should be another layer of planking placed over the present bridge for experience has shown that a single decking will not last long. No single decking can for long stand the wear and tear of traffic and twisted about by the weather. The upper sheeting could always be repaired when needed without interfering with traffic.

On 21 December 1900 the Corowa Free Press criticised the "cheese-pairing policy of the New South Wales Government .... and the unsatisfactory state of the bridge flooring" plus "before the advent of the wheat traffic ...... tenders be called for a complete (*new*) platform".

But piecemeal repairs and replacements continued until under the heading FLOOR AGAIN COLLAPSES, TRAFFIC AGAIN SUSPENDED, the issue on 1 August 1901 reported that a 16 ton wheat wagon had "broken through the decking and had become embedded up to the axle", followed by "what is urgently required is double decking throughout".

This advice was acted upon (just when has not been determined) and a top layer of longitudinal planks has been on the iron bridge and the approach viaduct for most of their service lives.

The 1892 bridge did not have an official opening but the "Old Pioneer" indicates that traffic began to use the bridge just before 6th January 1893. Its final cost was almost 17,000 pounds, equivalent to around $2 million in 1999. Relative to colonial economies, bridges were as expensive then as they are today.

SURVEY OF IRON LATTICE BRIDGES IN NEW SOUTH WALES

There are 18 iron lattice road bridges in New South Wales, all completed in the twenty year period 1873 to 1893, a shown in the following sheets.

The Hunter valley with five, has the greatest number of lattice bridges, four over the Hunter River and one over the Paterson River, next is the three over the Namoi River. There are three in the New England region and, at three sites in the Jemalong Shire, based on Forbes, there are spans from the 1882 Iron Cove Bridge, Sydney.

The number of spans per bridge ranges from 1 to 6 but not 4. There are only two single-span bridges and all the multiple-span bridges are continuous over the piers. The multiple-span bridges prior to 1887 have equal spans then come the six designs by John A McDonald in which he uses three unequal spans. Only one bridge breaks the McDonald pattern, the 2-span bridge at Dalgety in 1888.

The preferred deck system was tarred macadam on metal plates called buckled plates. Five of the surviving lattice bridges have this type of deck whereas another six have had the macadam replaced by concrete around 1939-40. A timber plank deck was the next type used of which five, including that at Corowa, survive. A more modern arrangement of a concrete slab on steel stringers has been installed at Aberdeen (1986) and the Jemalong Shire sites in 1956.

The end detail is also a distinguishing feature. Most of the first half of the bridges had vertical ends with a sharp radius curve at the top corners round onto the horizontal top chord. Only at two sites are the corners squared. All but one of McDonald's designs have their top flanges curving down gently at the ends of the bridges to almost a point above each end pier or abutment.

In addition to the following data base sheets, photographs are attached of the John Foord Bridge at Corowa and the Hunter Valley lattice bridges.

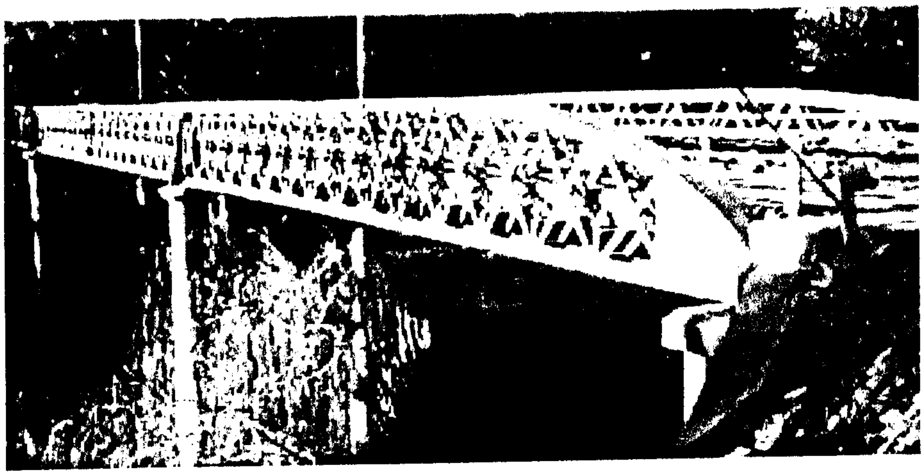
The National Trust in Victoria suggested a heritage survey of the bridges along the River Murray should be undertaken. That survey has been completed for the RTA by consulting engineers Hughes, Trueman and Reinhold in which they concluded that the John Foord Bridge was of State Significance. A summary of the River Murray bridges between Albury and the South Australian border is included here. It verifies the uniqueness of the Corowa bridge among the River Murray bridges.

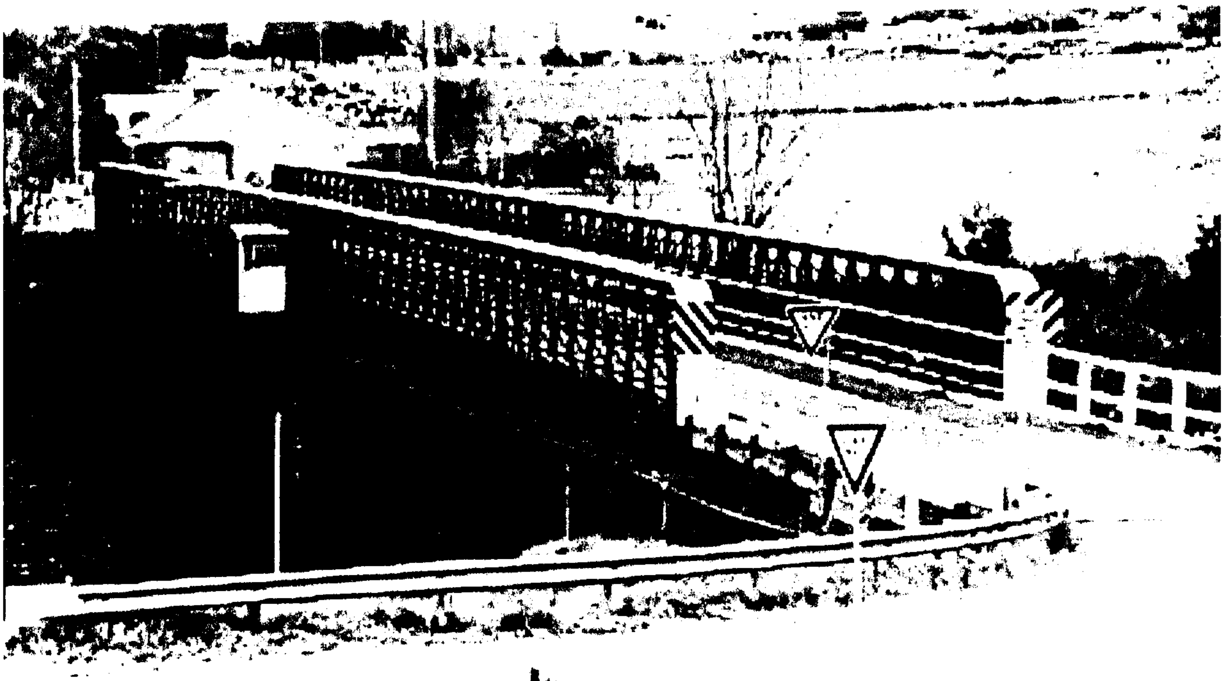
LATTICE GIRDER ROAD BRIDGES IN NSW (1997) - Sorted by YEAR

OCATION / NDERS CALLED	ROAD / CONTRACT 1	YEAR	No SPANS	SPANS (ft) / CONTRACT 2	END DETAILS	DECK MAT'L / OTHER	COMMENTS
ara River, Bawdens Br	Unclassed	1874	2	127, 127	Curved corners	Timber	
27/1/1870, p 259	GG 25/4/1870, p 959 Ironwork, Mather J			CHECK			Opened 13/4/1874 Ill Syd News
nter River, Muswellbrook	MR208	1881	2	127, 127	Curved corners	Timber	
4/7/1877, p 2681	CHECK Nov 1877 re ironwork, ex Head Wrightson &			Musson, John, Sydney, 1/4/1878, P 1362			Butterley iron sections
wydir River, Bundarra	MR73	1881	5	5 x 127	Curved corners	Buckled pl & macadam	
12/12/1876, p 4987	Ironwork ex England			Franklin F A, erect, GG 12/7/1880, p 3531			
n Cove, Sydney	Unclassed	1882	Varies	127	Square corners	Stringers & concrete	Jemalong Shire,3 sites ,1960
G 12/12/1876, p 4987	ironwork ex Appleby Bros, England			PWD day labour			Opened 1/11/1882
amoi River, Boggabri	MR357	1883	1	127	Curved corners	Buckled pl & concrete	
G 22/8/1882, p 4335	CHECK			Royce G H & Co, erect, GG 2/10/1882, p 5282 CHECK			
amoi River, Gunnedah	Unclassed	1884	2	127	Curved corners	Buckled pl & concrete	nearly complete 27/12/1884
HECK ALL							Opened early 1885 CHECK T&CJ
arramatta River, Gasworks Br	MacArthur St	1885	3	100, 100, 100	Curved corners	Concrete	
GG 24/10/1882, p5656	GG 18/6/1883, p 3342, ironwork, Robertson D&W			CHECK			Some iron ex Belge Providence
Gwydir River, Bingara	TR63	1886	6	6 x 127	Square corners	Buckled pl & concrete	
GG 6/3/1883, p 1256	CHECK			CHECK			
Halls Creek, Bingara	TR63	1886	2	90, 90	Curved corners	Buckled pl & concrete	
GG 20/3/1883, p 1521	CHECK			CHECK			
Namoi River, Manilla	TR63	1886	2	127, 127	Curved corners	Buckled pl & concrete	6 x 61ft deck lattice appr'ch
GG 6/3/1883, p 1256	Ironwork ex England			CHECK			Opened 17/3/1886 T&CJ 29/3/1905

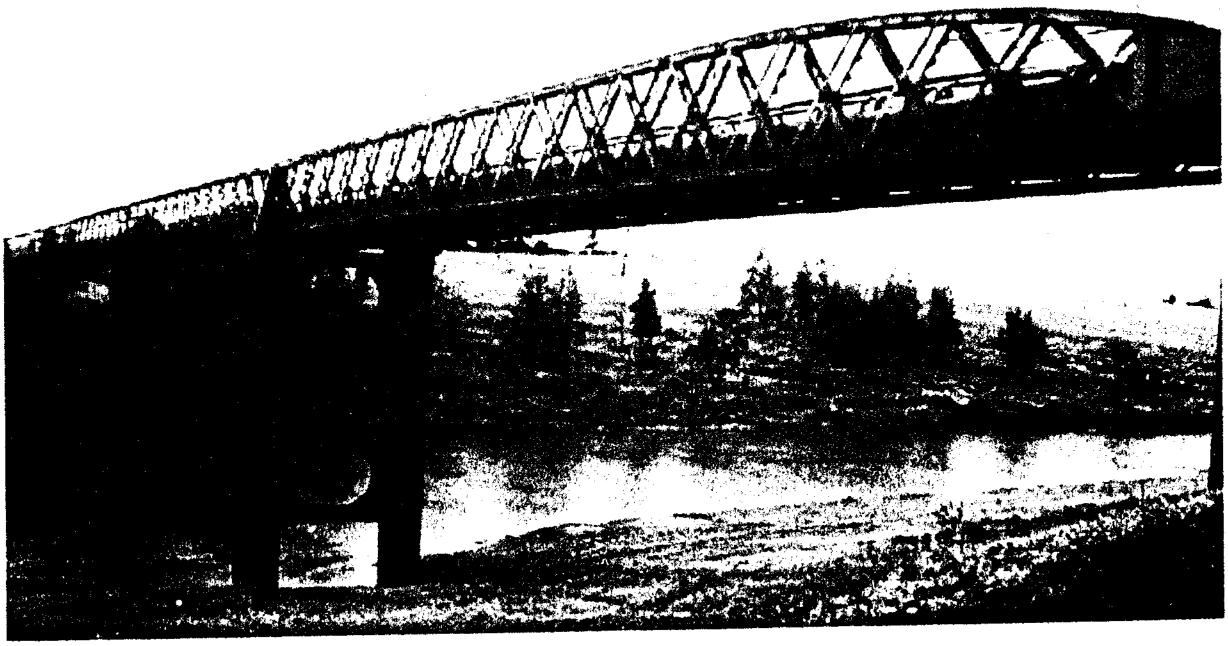
LATTICE GIRDER ROAD BRIDGES IN NSW (1997) - Sorted by YEAR

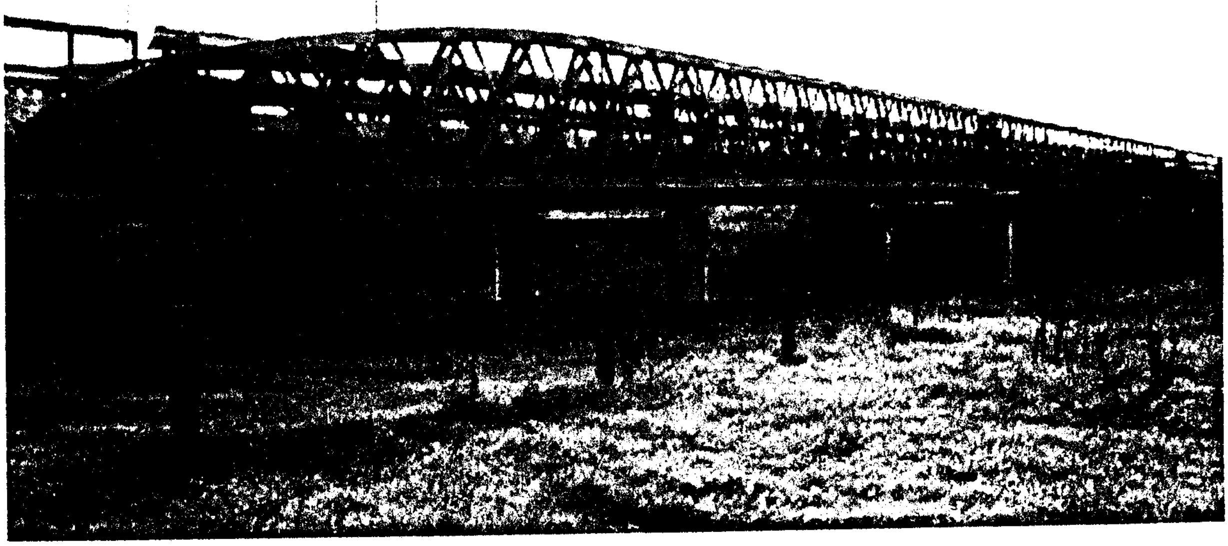
LOCATION / TENDERS CALLED	ROAD / CONTRACT 1	YEAR	No SPANS	SPANS (ft) / CONTRACT 2	END DETAILS	DECK MAT'L / OTHER	COMMENTS
Paterson River, Paterson	Unclassed	1888	3	91, 119, 91	Flat curves	Buckled pl & concrete	
GG 5 June 1885, p 3620	GG 11 Aug 1885, p 5195, ironwork, Robertson D&W			McKenzie & Burley, erect, GG 11 Aug 1885, p 5195			Opened 24/2/1888 T&CJ 10/3/1888
Snowy River, Dalgety	Unclassed	1888	2	140, 140	Flat curves	Timber	Opened 1/5/1889 T&CJ
GG 20 Feb 1885, p 1278	GG 2/11/1886, p 7539, ironwork, Ritchie R F			Gray J, erect, £ 4939, GG 10/1/1887, p 216			T&CJ 18/5/89, Harris&Evans, £6749 ??
Hunter River, Elderslie	MR220	1891	3	140, 182, 140	Flat curves	Timber	
GG 17 Sept 1889, p 6486	Morrison Stewart & Co, ironwork, GG 17 Jan 1890, p			Thompson Max then Carson J F, GG 21 Jan 1890, p 605			600 t ronwork "Essen", NMH 15/11/1890
Hunter River, Redbournberry	MR128	1891	3	91, 119, 91	Flat curves	Buckled pl & macadam	
GG 12 Apr 1889, p 2772	Morrison Stewart & Co, ironwork, GG 3 Aug 89, p			Burley Jesse, erect, GG 3 Aug 1889, p 5471			600 t ronwork "Essen", NMH 15/11/1890
Vale Creek, Perthville	MR252	1892	1	80	Curved corners	Buckled pl & macadam	
GG 22/8/1890, p 6603	McCormack J, ironwork, 9 Dec 1890, p 9434			Walker Jas, erect, GG 9 Dec 1890, p 9434			
Hunter River, Aberdeen	SH 9	1893	3	140, 182, 140	Flat curves	Stringers & concrete	
GG 29 Apr 1890, p 3436	Morrison Stewart & Co, Ironwork, GG 23 Sept 1890, p			McMaster O, erect, GG 23 Sept 1890, p 7392			600 t ronwork "Essen", NMH 15/11/1890
Lachlan River, Forbes	TR56	1893	3	112, 112, 112	Curved corners	Buckled pl & macadam	
GG 7/3/1890, p 1983	Carson R F, ironwork, GG 17/6/1890, p 4725			Downey W H, erect, GG 17 June 1890, p 4725			
Murray River, Corowa	TR86	1893	3	113, 140, 113	Flat curves	Timber	
GG 1 Apr 1890, p2861	Ironwork ex England on *Culgoc*			Downey & Co (Corowa Free Press) then PWD day labour			Opened 5/1/1893 (Corowa Free Press)



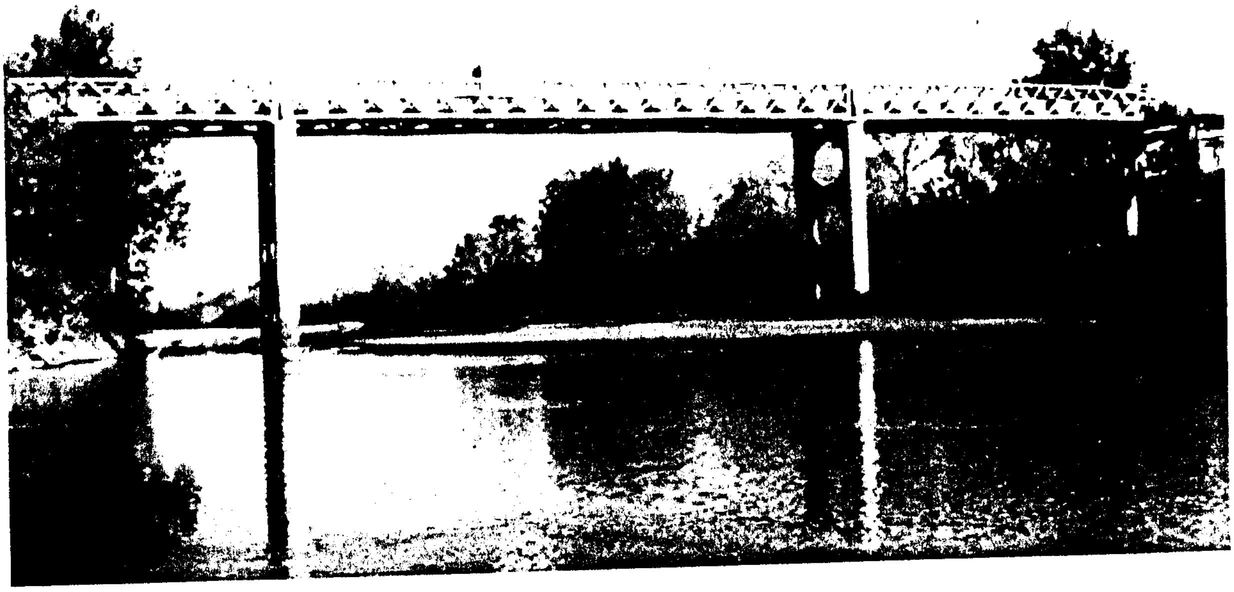


Lattice road bridges, Top: Corowa 1892 and Below: Muswellbrook 1881

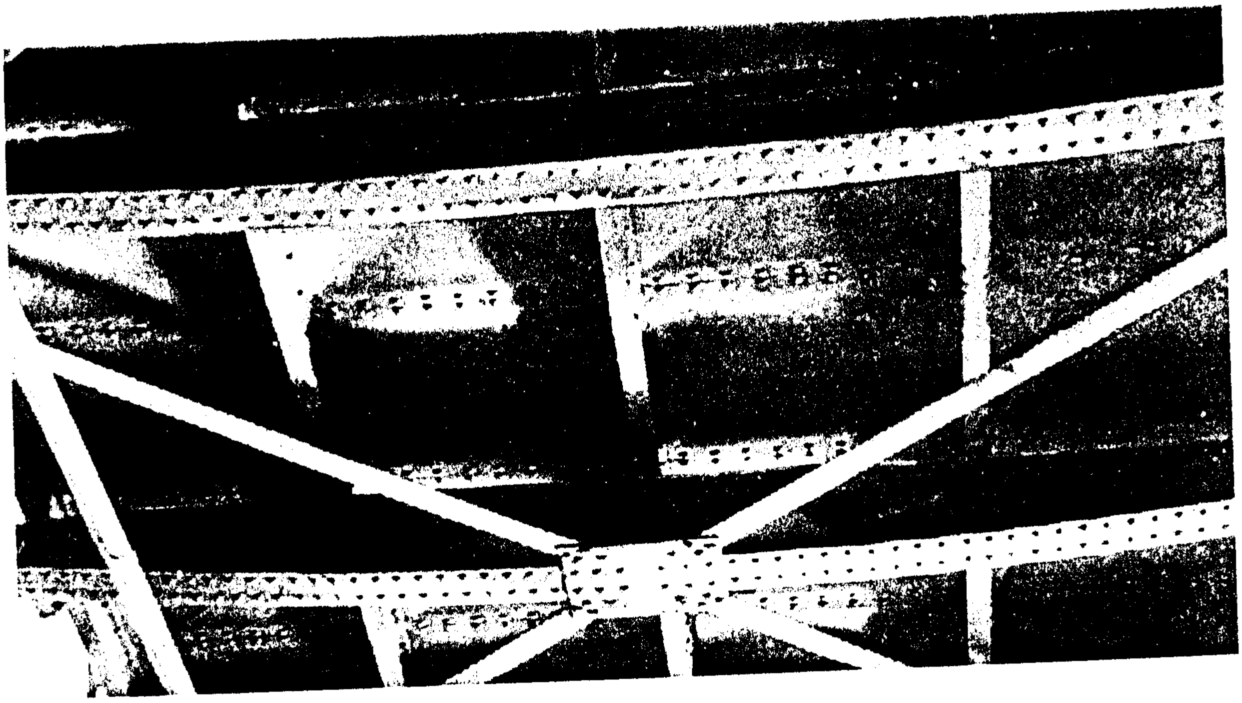




The longest 3-span lattice road bridges, 140-182-140 feet spans.
Top: Elders;ie 1891 and Below: Aberdeen 1893.



The shortest 3-span lattice road bridges, 91-119-91 feet spans.
Top: Paterson 1887 and Below: Redbourneberry 1891.



Redbourneberry Bridge. Top: Underside view of a buckled plate deck. It supports macadam or concrete toppings for a smooth riding surface. Below: Timber planks on the approach viaduct break up the asphalt coating hence a rough riding surface.

RIVER MURRAY BRIDGES

Albury to the South Australian border

LOCATION	ROAD	STRUCTURE*	YEAR
Albury	RAIL	2-span iron lattice trusses	1884
	SH 2	Prestressed concrete girders	1961&1990
Howlong	MR 197	1 Dare timber-steel truss	1908
Corowa	TR 86	3-span iron lattice trusses	1892
Mulwala	MR 314	3 steel Pratt trusses	1924
	VLINE	Multi-span steel	1938
Cobram	MR 226	1 Lift span & 2 DeBurgh timber-steel trusses	1902
Tocumwal	VLINE	1 Lift span & 2 steel lattice trusses	1895
	SH 17	Prestressed concrete box girders	1987
Barmah	MR 391	Prestressed concrete girders	1966
Echuca	SH 21	3-span iron plate web girders	1879
	VLINE	Prestressed concrete box girders	1989
Barham	MR 319	1 Lift span & 2 DeBurgh timber-steel trusses	1905
Murrabit	Unclass'd	1 Lift span & 2 steel plate web girders	1926
Swan Hill	TR 67	1 Lift span & 2 Allan timber trusses	1896
Nyah	Unclass'd	1 Lift span & 2 steel plate web girders	1941
Tooleybuc	MR 222	1 Lift span & 2 Allan timber trusses	1925
Robinvale	MR 583	1 Lift span & 6 steel plate web girders	1925
Mildura	SH 14	Prestressed concrete box girders	1985
Abbotsford	SH 22	1 Lift span & 4 steel Pratt trusses	1928
		* Main river spans only listed	

TYPE SUMMARY (20)

Allan truss	2
Dare truss	1
DeBurgh truss	2
Lattice truss	3
Lift spans	9
Pratt truss	2
P S C girder	4
Plate girder	5

The First Sixty Years of Metal Bridges in New South Wales

D.J. FRASER, M.I.E.AUST.

SUMMARY Prior to the recent advent of box girder construction in steel or prestressed concrete, bridge spans in the range of 50m to 150m were dominated by the steel truss, the most common form being the American Pratt truss. This situation prevailed in New South Wales from the beginning of this century, but was not the case in colonial times. In the second half of the nineteenth century, bridge engineers in New South Wales used British technology, consequently, iron cellular and iron lattice girders were the standard types of bridges adopted for crossing major rivers. This paper traces the evolution of metal bridges in New South Wales during the period 1863 - 1925, and focusses attention on the technical and non-technical factors that led to the rapid changeover from British to American bridge technology after 1890.

1 INTRODUCTION

Until 1916 when the steelworks at Newcastle were established, iron and steel structural sections and plates were expensive imports for New South Wales. Consequently, metal bridges were very expensive projects. Costs could be between three and five times that of a timber structure, occasionally a lot more. Metal bridges were, therefore, used sparingly, starting in 1863.

Table I shows that timber bridges outnumbered metal bridges by about eight to one prior to 1916, but the complete reverse was the case in the 1920's when steel girders and trusses dominated the construction of most bridges. By then, the technical superiority of metal bridges was well established for a wide range of spans, figure 1. This situation was further enhanced as the supply of cheaper local steel steadily increased.

For much of the period under review, 1863 - 1925, the construction of railways and roads absorbed most of the funds allocated to public works, figure 2. The railway vote in particular averaged over 50% with peaks in excess of 60% during the boom years of the 1880's.

Despite the lion's share of public works funding, the railway and road engineers were under intense pressure to minimise costs especially for bridges, hence the extensive use of timber, so much so that New South Wales became known as "the timber bridge colony" (Fraser 1985). Proposals for metal bridges were the subject of detailed examination and often lengthy debate in the New South Wales Parliament. On one occassion, in 1861, the Legislative Assembly refused to vote money for the bridge over the Hunter River at Singleton until John Whitton tabled the plans showing that timber laminated arches would be built (Royal Commission on Bridges 1884 - 1886). However, at many sites, large span metal bridges were the best solutions. Under british-trained engineers John Whitton (railways) and William Bennett (roads), the plate-web girder and the lattice-web girder, figure 3, became the standard types of metal bridges in colonial New South Wales.

Dr D J Fraser is a Senior Lecturer, School of Civil Engineering, University of New South Wales. (Paper G1182 submitted on 12 August 1985).

British technology was dominant until 1890 when Whitton and Bennett retired. Thereafter, a rapid changeover to American technology took place, initially for railway bridges under Henry Deane and then for road bridges, in the early years of Federation, under prominent designers such as Percy Allan and E. M. de Burgh.

TABLE I

SUMMARY OF ROAD AND RAIL BRIDGES BUILT IN NEW SOUTH WALES 1851-1925, FOR SPANS OVER 40 FEET (13m) BUT EXCLUDING ALL TIMBER BEAM BRIDGES.

Period	1851-60	1861-70	1871-80	1881-90	1891-1900	1901-10	1911-15	Sub-total	1916-20	1921-25	Totals
Masonry arches	*1 5	4 8	2 2	- 1	1 4	- 1	- 9	8 30	1 8		9 38
Timber arches	5 4	3 1	1 -	2 2				11 7			11 7
Timber trusses	2 -	25 -	80 -	69 9	108 6	39 13	12 1	335 29	18 1	1 -	354 30
Metal lattice		1 -	4 2	13 10	6 2			24 14			24 14
Metal trusses		2 -	2 -	2 3	1 10	2 7	1 21	10 41	2 8	1 6	13 55
Metal girder		- 7	1 4	2 12	8 11	4 2	- 4	15 40	** **	** **	** **
Opening bridges	1 -	3 -	2 -	9 -	12 -	10 -	1 -	38 -		3 -	41 -
Reinf conc					9 -	14 -	17 -	40 -	**	**	** -
Totals	18	55	99	132	178	92	66	640	**	**	**

* upper figures apply to road bridges,
lower figures apply to rail bridges.

** standard designs , locations and dates not fully recorded , exact totals unknown.

We are fortunate that most of the iron and steel bridges of the period 1863 to 1923 have survived. They are evidence of an important phase of our engineering heritage.

This paper traces the technical development of metal bridge superstructures in New South Wales against a backdrop of concurrent social, political and economic factors.

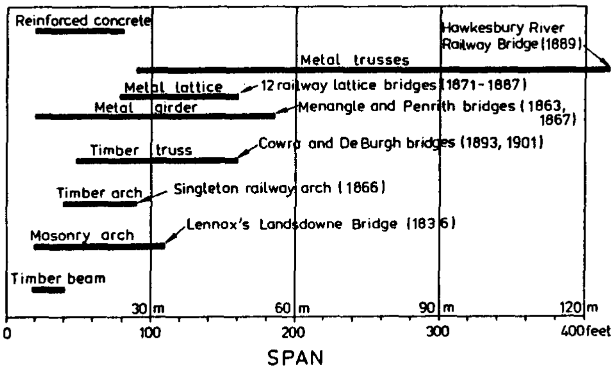


Figure 1 Bar graph showing the economic ranges of spans for the various types of bridges used in New South Wales. The flexibility of application of metal girders and trusses made them the preferred choice, but their costs were very high.

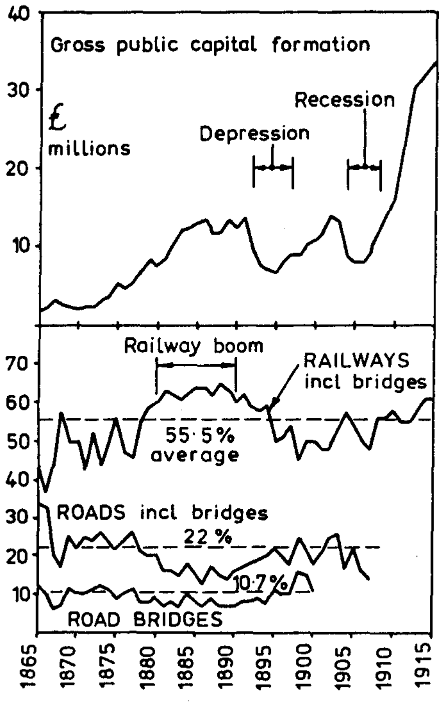


Figure 2 Economic growth, and decline, in New South Wales during the fifty-year period 1865-1915 as indicated by the gross public capital formation (cost of public works). The distribution of that capital shows the dominant position of the railways. (from Butlin 1962).

1.1 BRITISH BRIDGES

Metal bridges in New South Wales of british origin were all built in the late colonial period between 1863 and 1897. The superstructures comprised four basic types, (1) cellular girders, (2) Warren girders or trusses, (3) lattice girders or trusses and (4) plate-web girders, figs 3 to 9. Wrought iron was used almost exclusively. The piers were often of masonry construction but there were many sites where pairs of braced metal cylinders were used, built up from cast-iron rings and filled with concrete.

Cellular girders

The cellular or tubular girders in New South Wales had their origins in the famous tubular bridges of Robert Stephenson, the Conway (1849) and Brittania (1850) Bridges in Northern Wales, and the Victoria Bridge over the St.Lawrence River, Canada (1860). Only the Conway Bridge survives. The cellular form of construction, figure 4, was developed from a series of model tests by William Fairbairn and the analytical investigations by Eaton Hodgkinson. Their work showed the superiority of these girders in resisting collapse by lateral buckling.

The maximum span of Stephenson's tubular bridges was 460 feet (140m) and this justified the tunnel-like construction, but when John Whitton adopted this arrangement for the first series of major bridges for the railways of New South Wales, the maximum span was only 198 feet (60.5 m). He was therefore able to use shallower girders in the form of pony or half-through bridges, figure 5.

Four of these bridges were constructed, two over the Nepean River at Menangle (1863), figure 6, and at Penrith (1867), and two crossings of the Wollondilly River (1869). The latter were removed in 1914 when the Main Southern Railway was duplicated on a new alignment. The Menangle Bridge is still in use as a railway bridge but the spans have been halved by additional piers built in 1928. The Victoria Bridge at Penrith was originally designed for double track railway but was shared by road traffic and a single track for its first forty years. In 1907, heavy-duty double-track were completed immediately downstream and the Victoria Bridge has been used only for road traffic ever since.

The Wollondilly bridges were simply-supported girders and only had cellular construction for their top flanges, whereas the Menangle and Penrith bridges were three-span continuous with both flanges cellular throughout. The original designs were by John Whitton but were checked by John Fowler (of Firth of Forth Bridge fame) in London using the relatively new theories of bending, deflection and formulae for predicting points of contraflexure. All four bridges were fabricated in England.

Cellular girders were a very expensive form of construction. This can be demonstrated in two ways. Firstly, the Menangle Bridge cost £94,562 in 1863 which in 1984 was equivalent to $6 millions, the conversion is based on a cost index of 0.14 relative to 1967 and a further factor of 4.48 to 1984 (Pope 1984) plus the 1966 changeover to decimal currency. A modern replacement would cost less than half that indexed cost. Secondly, the Penrith Bridge cost £100,000 in 1867 and was replaced in 1907. Its index cost for that year would have been £90,713 (0.14 for 1867 and 0.127 for 1907), whereas the replacement Pratt trusses cost only £38,000.

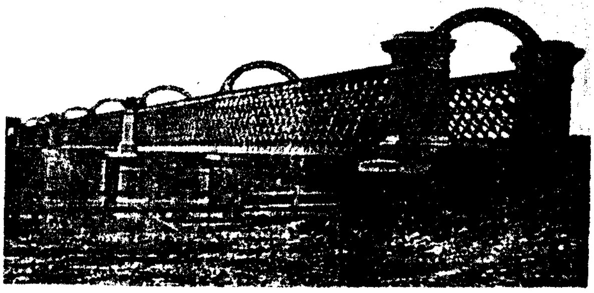


Figure 3 Typical examples of british bridge technology, lattice girders (for road and rail), and the plate web girder. Braced cylindrical piers were preferred and the plated diaphragms minimised the trapping of flood debris.

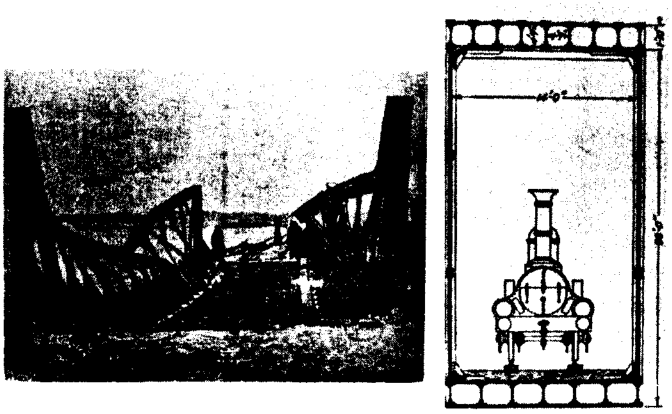


Figure 4 Girders were prone to collapse due to lateral buckling of their compression flanges. Fairbairn and Hodgkinson demonstrated the effectiveness of cellular construction.

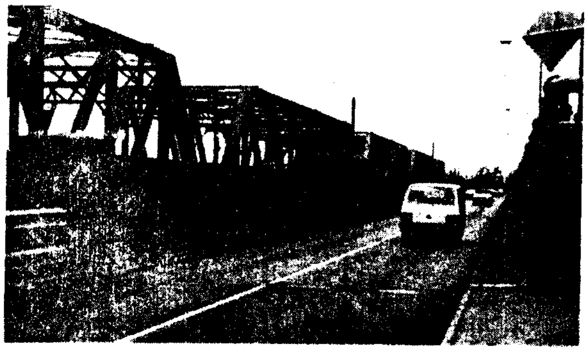
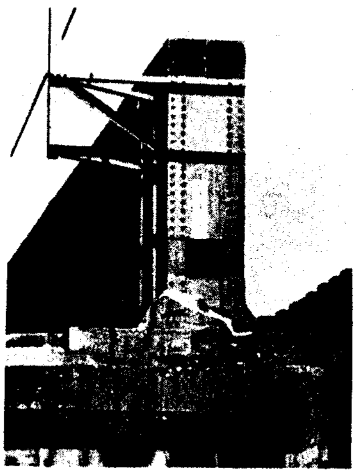


Figure 5 John Whitton's cellular girders were not deep enough to form tubes, hence the half-through or pony construction. Note the adjacent through trusses.



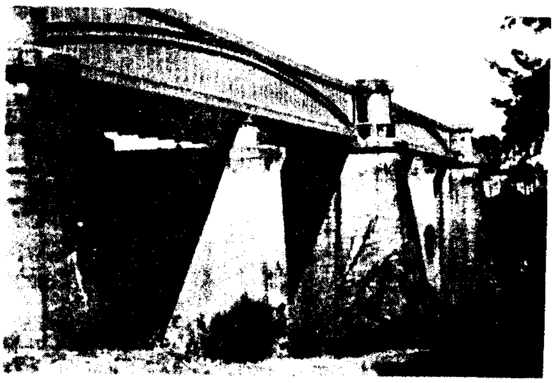


Figure 6 The 1863 Menangle railway bridge and its cellular flange. The arch ribs are purely decorative.

Warren trusses

The first major iron bridge for road traffic in New South Wales was the 1867 Warren or single lattice truss bridge, figure 7 , over the Murrumbidgee River at South Gundagai known as the Prince Alfred Bridge. The bridge is still in use despite the recent deviation of the Hume Highway a mile downstream. The river crossing had become a major obstacle for travellers and teams following the Hume and Hovell route to the Riverina and Victoria, and there had been regular petitions and deputations to the Colonial Government for a bridge.

Successive governments deferred on the grounds of low traffic flows and the high cost of any bridge project to cross the half-mile flood plain, but political and commercial factors forced the Government's hand. The merchants at Wagga Wagga favoured trade with Victoria since that colony's railway had reached Echuca in 1864, and they accused the distant Sydney-based Government of neglect (Ill.Syd News 1864). They formed a joint-stock company and built a substantial three-span timber bridge over the Murrumbidgee River in order to direct traffic from the surrounding districts through the town. It was reported that "as a financial speculation the bridge has proved successful".

A similar bridge had been erected over the Murray River at Albury so the New South Wales Government was forced to act in order to turn the flow of wealth towards Sydney. Not only was a bridge planned but a "Rolls Royce" bridge in the form of an expensive iron structure was approved as a clear indication to the south-western districts of the Government's legitimate interests in those regions.

Initially, only the three-span iron truss bridge over the main channel at South Gundagai was built during 1865-67 at a 1984 indexed cost of $1,850 per m² (3½ times the timber truss rate), and the road continued on the river flats. There was great rejoicing for "one of the noblest structures of the kind in the colony, a triumph of human skills, energy and perserverance over natural obstacles" (Ill.Syd.News 1868). By 1869 the long timber viaduct was completed thereby ensuring a flood-free crossing. The present timber viaduct was built on a new alignment in 1896.

The iron bridge has some unique features as shown in figure 7. The piers are pairs of braced cylinders six feet in diameter, nine feet high, built up from segments bolted together. This form of pier construction set the pattern for nearly all major bridges for the next sixty years. The cast-iron segments were made "in the Colony from Australian iron from the Fitzroy mines" (Bennett 1871). This also set a pattern of progressively more local involvement in the manufacture and supply of bridge components, the construction of foundations and the erection of bridge superstructures.

Each of the Warren trusses is a genuine pin-jointed structure, there is only a single large-diameter bolt at each joint. Bennett chose this system "as requiring least workmanship on the ground,and, from the expedition with which it can be erected, incurring least risk from violent floods". And the support for each truss is a fascinating arrangement, the trusses are supported at the top by a short cantilevered extension of the top chord resting on vertical iron posts projecting up from the piers which finish level with and are connected to the bottom chords of the trusses.

The Prince Alfred Bridge appears to be the only example, in the period under review, of the use of Warren trusses for a road bridge. The merit of this form of construction seems to have been completely over-shadowed by the widespread use of the lattice girder (see next section). The railways too, seem to have used the Warren truss for only one project. the replacement of timber viaducts between Parramatta and Penrith around 1884 (Town and Country Journal 1884, SRA Archive notes for 1888-92).

A series of deck Warren trusses, figure 8, were erected at fourteen locations. They were of local design by G.W.Townsend, 42 feet (12.8m) span, 5 feet 3 inches (1.6m) deep and each complete span weighed 14 tons. Technically, the design was routine and each was a minor bridge project, but at the time they were seen as important indicators of colonial engineering expertise, "built in the Per-Way workshops, the pairs of light girders were subject to a severe test with complete success, demonstrating that girder work can be done in the colony both cheaply and well" (T & C J 1884).

Lattice girders

The lattice girder bridge, figure 3, was almost the exclusive choice for major bridge projects in New South Wales for a quarter of a century, from 1870 to 1895, a period of bridge engineering dominated by the long-serving Chief Engineers John Whitton (railways 1856-90) and William Bennett (roads 1862-89). There were 41 of these standard british lattice girder bridges (27 road, 14 rail Best and Fraser 1982) during their terms of office, but only 12 American style trusses (O'Connor 1983).

The lattice girder was a more economical form of construction than the cellular girders of the 1860's. The latter weighed 0.78 ton/m² and cost $4,500/m² or $6,000/ton (indexed to 1984) whereas the lattice girders weighed 0.4 ton/m² and cost $1,480/m² or $3,700/ton. For comparison timber truss bridges of that period had an indexed cost of between $600 - $1,000 per m².

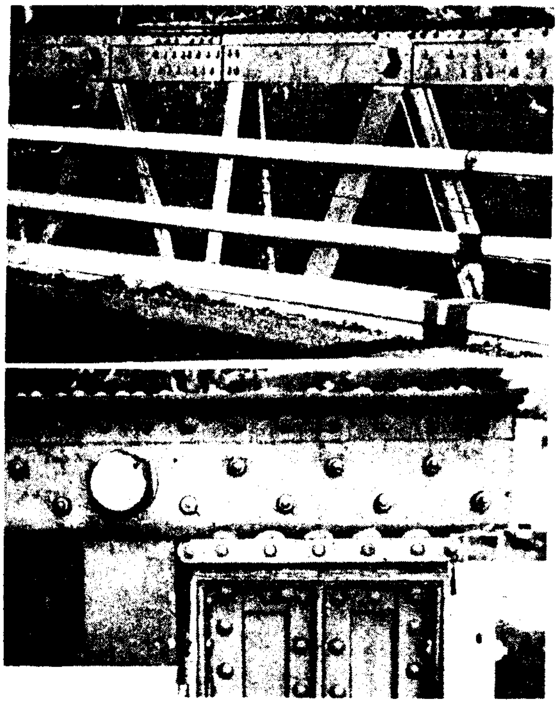
Despite the cost advantage, all lattice girder bridges were fully imported so they were still a relatively expensive form of construction for their day. For example, the 1871 railway bridge over the Hunter River at Aberdeen had an indexed cost of $960,000 when replaced in 1979. The new plate-web girder bridge, designed for much heavier and faster traffic, cost only $550,000.

Railway lattice bridges were of course more substantial than those used for road traffic. The former are all about 4m deep with 7, 6 and 4 triangulations within the lattice web system. Lattice road bridges are only 2m deep and only employ 2 triangulations, consequently, they are sometimes referred to as double Warren trusses.

Although the initial cost of these colonial lattice girder bridges was high, in the long-term they have proved very cost-effective. Nearly all continue in service with an average life of around 100 years. This type of bridge was as much a part of colonial New South Wales as reinforced concrete became to the 1930-60 period and prestressed concrete to more recent times.

Plate-web girders

The iron girder and plate-web girder, figure 9, was essentially a british development, although there was technical input from Europe. The impetus for its development and use came from the Railway Mania, a period in the 1840's in England which saw a frantic rate of railway construction. Masonry arches were too expensive and too slow to build, timber was in



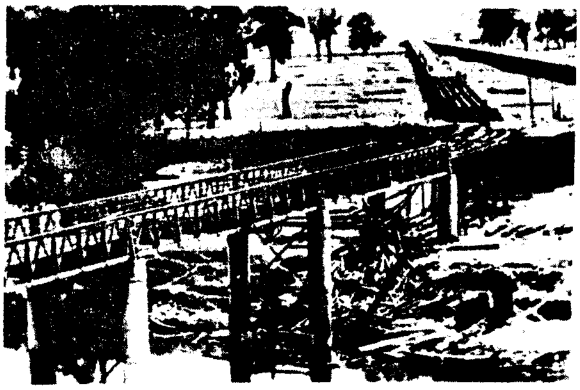


Figure 7 The 1867 Prince Alfred Bridge, Gundagai.

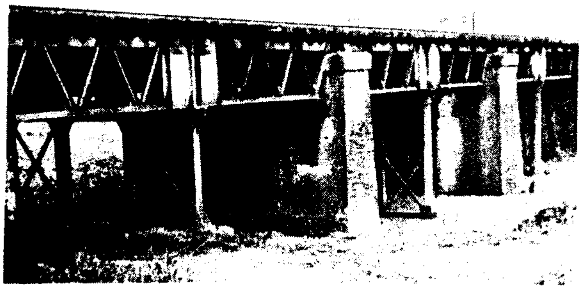


Figure 8 These Warren railway trusses near Werrington are over 100 years old. They were acclaimed as examples of local engineering skills.

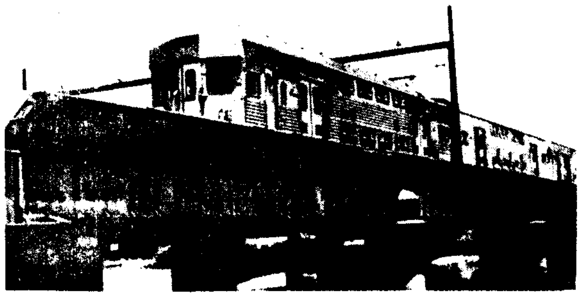


Figure 9 The plate web girder became a standard for medium-span bridges during the 1880's. The 1884 bridge over Cooks River, Tempe, demonstrates the long life of these bridges.

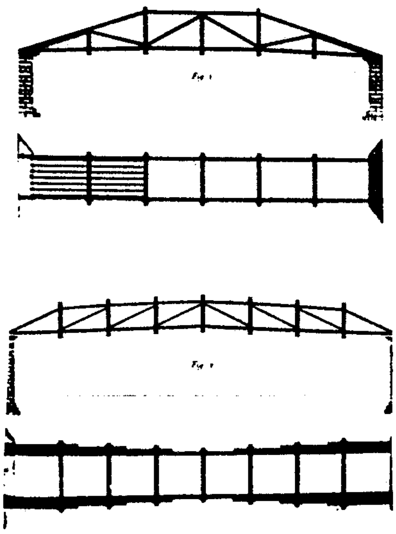


Figure 10 Palladio timber trusses c1550

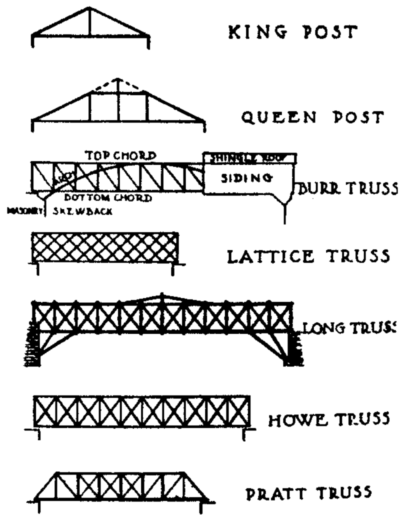


Figure 11 American timber truss bridges of the 1850's. The Howe, Pratt and later the Whipple trusses proved to be economical and durable when adapted to iron and steel construction.

very short supply and its structural forms (solid girders and queen post trusses) were of limited structural capacity.

Metal bridges were the solution, and , at that time, Britain had a rapidly expanding iron industry so was able to meet the demands of the Railway Mania for relatively cheap bridges that could be quickly fabricated and erected. The first of the metal girders were made from cast-iron, and featured enlarged tension flanges to account for the tensile weakness of cast-iron. But cast-iron also had low impact resistance and there was a spate of bridge failures. The solution to impact brittleness was the use of the ductile, but more expensive, wrought iron. This higher quality material enabled girder shapes of more slender proportions to be used which, in turn, exposed the bridge to the dangers of lateral buckling failures, figure 4.

Fairbairn and Hodgkinson analysed the problem of buckling of compression flanges and carried out a series of model experiments. Their work culminated in the tubular and cellular forms of construction noted earlier.

By the time John Whitton was planning the railway extensions in the 1860's through the Great Dividing Range, the cast-iron girder had been displaced by the wrought iron girder, and Whitton's use of the cellular girder has already been described. At the same time he did use plate-web girders for the shorter spans of the Wollondilly set of bridges,figure3.

During the 1870's, funding for railways in New South Wales was severely restricted, consequently, Whitton was forced to use timber bridges, girder, truss and arch (Fraser 1985). The only exceptions appear to be the iron lattice girder bridges at Aberdeen (1871) and at Bathurst (1876), and the plate-web girder over Solitary Creek west of Lithgow in 1872.

In the 1880's, however, the situation was quite the opposite as New South Wales experienced its own form of Railway Mania. The length of completed railways trebled as the main lines were pushed to the distant borders at Albury (1883) and Wallangarra (1888), and to Bourke in 1885 to divert the wool from the river trade to Sydney.

For medium spans in the range 15-30m (50-100 feet), the iron plate-web girder was an ideal transition from the 10m (30foot) timber structures through to the 48.5m (159 foot) lattice girder. It meant that a series of progressively larger spans could be used between the abutments and the main spans over the river channels.

The long-term superiority of the metal girder bridge was soon acknowledged by railways administrators. Since the 1890's there has been a long-standing policy of renewing timber bridges in steel (or concrete) and the steel plate-web girder has become one of the principal types of bridges on all new lines.

As for road bridges, very little use was made of the iron/steel girder by the Public Works Department. Their bridge programme almost exclusively used timber structures, beams and trusses Fraser 1985). Where lattice girder bridges were used, the approach spans were nearly always timber.

2 AMERICAN BRIDGES

The American influence on bridge engineering in New South Wales, at the end of the colonial period and in the first twenty years of federation, was almost entirely through the truss form of construction.

The truss was not an American invention. It had been used in Britain and Europe since Medieval times , mainly for roof trusses. Palladio c1550 had demonstrated the concept of a timber truss bridge,figure 10, but due to the demands for wood by ship builders, the iron industry for charcoal, and for domestic heating, relatively few timber bridges were built. Britain and Europe relied on the masonry arch and gradually changed over directly to metal bridges.

In America, the situation was the reverse, an iron industry in its infancy plus high costs for the imported product, few skilled workers for masonry construction, but most importantly, an almost infinite supply of timber. Consequently, timber bridges dominated American bridge engineering until the 1860's. Figure 11 shows some American timber trusses.

There were about twenty viable designs (Wilson 1871) for timber truss bridges but eventually only two showed all-round suitability. These became the principal types in New South Wales after 1892, The Howe truss for timber road bridges and the Pratt truss for steel railway bridges.

By the 1870's the American iron and steel industry had become established and the logical step of making all-metal trusses occurred. As with timber trusses, there was a great variety of styles. The Whipple and the Pratt trusses became the most popular in New South Wales, particularly the latter. It became the standard for long-span bridges, road and rail, during the first half of the twentieth century. This dominance started in 1892 but three bridges built during the previous twelve years had indicated the pending changeover.

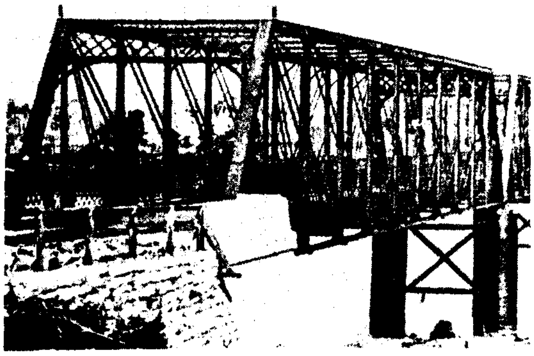
American bridges pre-1892

The three American-style bridges that began the tide of change from British to American technology are shown in figure 12. A characteristic feature of American metal trusses, as used with each of these bridges, was the pin-jointed construction. It consisted of a large-diameter pin at every joint and, multiple eye-bars for the tension chord and diagonal members, figure 13. The reasons for this method of construction were (1) to eliminate the problem of quality control of field rivetting and (2) reduce assembly/erection times. For example, a 100m (300 foot) truss was completed on a site in America in 36 hours.

A span of the Shoalhaven River bridge was on display at the International Exhibition held in Sydney in 1879, and the Judges acknowledged "that this type of bridge can be put together with great rapidity" which was clearly demonstrated on site, figure 13, when a typical span was assembled and floated into place in 4½ days (Town & Country Journal 1880).

Another feature of the American-style metal truss that was in marked contrast to the British lattice girder, was its height and light-weight appearance. The American truss towered over the vehicles using the bridge. It was truly a through bridge with horzontal bracing between the top chords and portal frames at the ends. The lattice girder was too shallow for this treatment and was part of the family of bridges referred to as pony/half-through bridges.

In the case of the Shoalhaven River bridge, the American design showed a significant cost advatage, £24,709 as against £35,758 for a lattice bridge. But such was the strength of British attitudes that the Judges concluded that "taking all different points into consideration, that unless under peculiar cir-



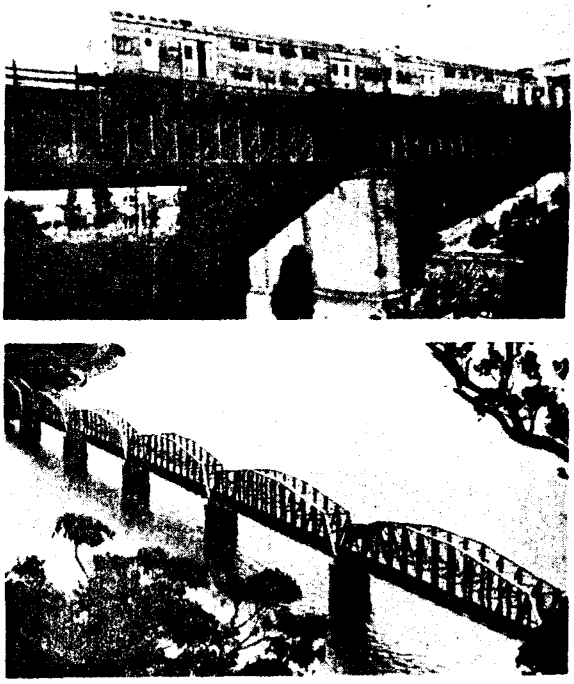


Figure 12 Three early American trusses in colonial New South Wales, at Nowra (1880), at Lewisham (1886) both extant, and the 1889 Hawkesbury River railway bridge.

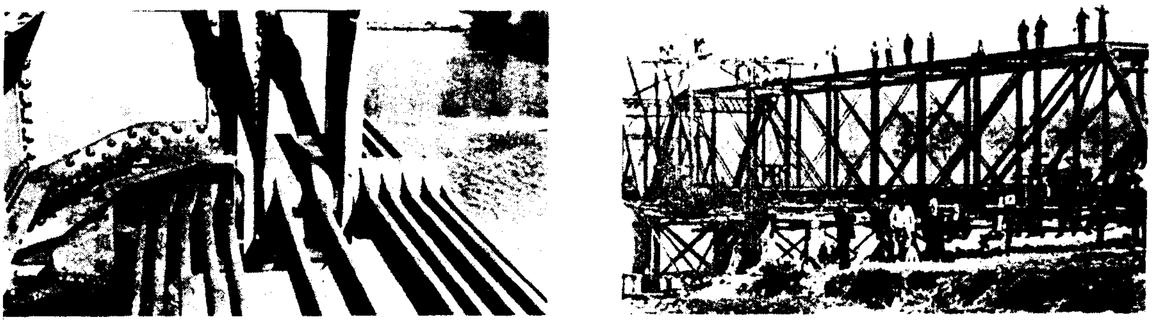


Figure 13 Eye-bars and large diameter pins (left) were a feature of early American metal trusses. At right is the erection of a Whipple truss at Nowra.

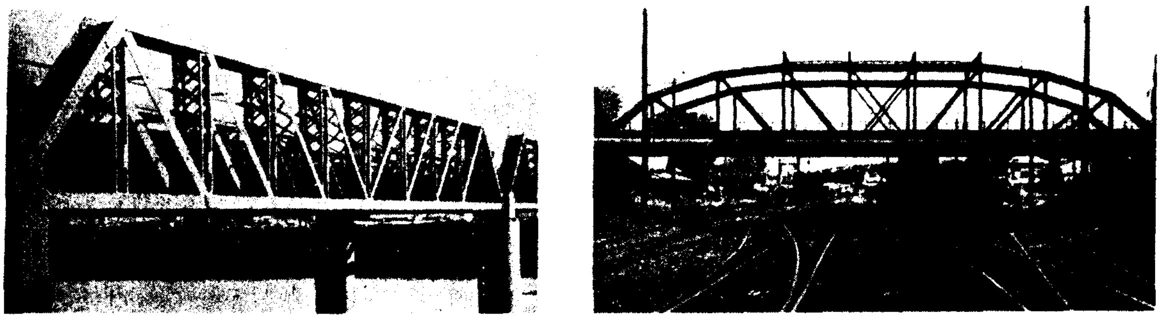


Figure 14 The 1870 Denison Bridge and the 1888 Rocket Street bridge, both in Bathurst. Their success did not hasten the introduction of American bridge technology.

cumstances, the lattice bridge is preferable for both railways and roads in this Colony". The introduction of American bridge technology was virtually blocked for another decade.

But there were two important exception for railway bridges. Firstly, the original stone arch viaduct over Long Cove Creek, Lewisham, was replaced by Whipple trusses in 1886. This type of work was the resposibility of the Existing Lines Branch under George Cowdery who had no time for Whitton and his set ways. Indeed, it was a petty squabble between them in 1883 that precipitated the Railway Bridge Inquiry of 1884-86.

The other exception was the first Hawkesbury River bridge, the largest bridge project in New South Wales prior to the Sydney Harbour Bridge. Whitton had proposed a series of lattice spans, but the sheer magnitude of the work together with criticism of Whitton's autocratic manner caused the Government to seek the advise of overseas bridge experts. Consequently, world-wide tenders were called and the Union Bridge Company of America was the successful tenderer. The bridge was constructed between 1885 and 1889, and incorporated seven pin-jointed trusses of a modified Baltimore design (King & Fraser 1983).

Also, there were two road Pratt trusses. In 1870 , the laminated timber bowstring arches (the Denison Bridge) over the Macquarie River at Bathurst were replaced by iron pony trusses, figure 14. It was a local design by G.A.Morrell and locally fabricated by Peter Nicol Russel and Co. using iron from the Fitzroy Iron Works, Mittagong (Evans 1984). The success of the work, with its high local content, seems to have been ignored at the time. Also at Bathurst is the Rocket Street bridge, figure 14 , over the railway yard and completed in 1888. It is tall enough to have overhead bracing and has a "hog backed" top chord which is another common feature of American truss bridges.

Neither bridge has pinned joints, both are of all-rivetted construction, which highlights the principal objection to pin-jointed construction, namely that despite the simplicity of joint detail and speed of assembly, pin-jointed trusses were difficult to strenghten. Removing the pins destroyed the structural integrity of the joints. Rivetted construction,however, was more amenable to alteration.

Colonial bridge engineers appear to have been aware of these factors because after 1892, with the adoption of Pratt truss bridges, only one pin-jointed bridge was built in New South Wales, the 1903 railway truss over the Murrumbidgee River at Gundagai.

American bridges post-1892

The first railway Pratt truss in New South Wales was built across the Yass River in 1892 to carry a branch line into Yass Town, figure 15. When indexed to 1984 it cost $1,130/m² which is 24% less than the cost of lattice construction. In 1894 five similar bridges were completed on the Lismore-Murwillumbah Line, and deck Pratt trusses were built in the Newcastle/Hunter Valley region. All showed the same cost advantage. These bridges set the pattern for major bridge construction in New South Wales into the twentieth century. This technological changeover (from British to American) had two important non-technical factors, one involving a change in administration, the other a change in design personnel.

Firstly, following the dispute between Whitton and Cowdery, the Railway Bridge Inquiry, and the open hostility betwee Whitton and Commissioner Goodchap, the Railway Construction Branch was transferred to the Public Works Department in 1888. Secondly, John Whitton retired in 1890 and was succeeded by Henry Deane. Then William Bennett died and Robert Hickson was appointed Commissioner for Roads and Bridges.

Both new appointees were actively involved with contemporary learned societies such as the Engineering Society of NSW, the Sydney University Engineering Society and the Royal Society, as were many of their colleagues. Collectively, they constituted a new breed of engineers who were more in touch with overseas engineering developments. For the next thirty years, bridge design was in the hands of such prominent engineers as Percy Allan, E.M. deBurgh, Harvey Dare, J.W. Roberts and J.J.C. Bradfield.

The greatest boost to the use of American Pratt trusses came with the construction of the North Coast Railway from Maitland to Casino during the period 1911 to 1923. In all, there were twenty-two crossings of major coastal rivers and their tributories, involving large-span Pratt trusses, figure 16. J.W. Roberts' 1910 paper is an excellent summary of all aspects of bridge design and construction for that project.

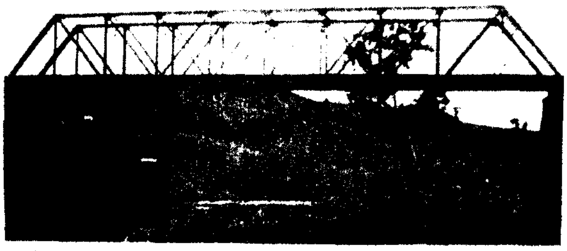
A programme of bridge renewals and of providing new bridges on deviations, duplications and new lines added many more steel Pratt trusses. The weight and speed of steam locomotives left little choice, so much so, that of the 56 iron/steel trusses built between 1892 and 1925, only five were road bridges (O'Connor 1983), figure 16. The local engineers modified the American designs in a number of ways, the most obvious being the elimination of pin-joints and eye-bars for the bottom tension chords ; rivetted-gusseted joints and built-up sections were used instead. Another change was from double flats for tension diagonals, figure 17, to rolled sections or built-up sections.

Local contractors and fabricators became more involved, figure 18, with bridge projects to the extent that all the North Coast Railway bridges were fabricated by Sydney-based firms such as Clyde Engineering Co., Sydney Steel Co., R.L. Scrutton and Co., R. Tulloch and Co. and the Railway Workshops; also, the Government Dockyards at Newcastle. However, most of the steel was imported, but this gradually changed to local supply once the steelworks at Newcastle was established in 1916.

There was also a change in design philosophy, or rather, a return to the policy of John Whitton,namely, "build to a high standard even though cost are high, otherwise maintenance, strengthening and replacement costs will reveal the false economies of cheap initial solutions". Consequently, all the Pratt trusses were designed for loads and impact allowances much greater than indicated by the contemporary traffic conditions. The result was a series of large heavy structures, figure 19, that continue to give satisfactory service after 70 or more years.

3 MOVEABLE SPAN BRIDGES

The paper has dealt exclusively with large-span position-fixed bridges for which the iron/steel girder or truss was the only viable solution during the period under review, 1863 - 1923. However,metal spans were used in other bridge situations, particularly for the moveable spans of opening bridges. The size of the moveable span was kept to a minimum consistent with size of river craft and operating effort, so they were comparatively modest. Details have been given in another paper (Fraser 1985).



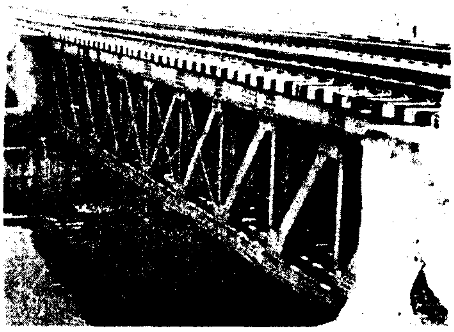


Figure 15 The beginning of a new era, the 1892 through Pratt truss at Yass and the 1898 deck Pratt truss over the Styx River, Newcastle.

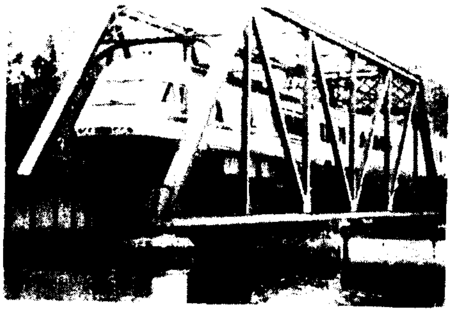
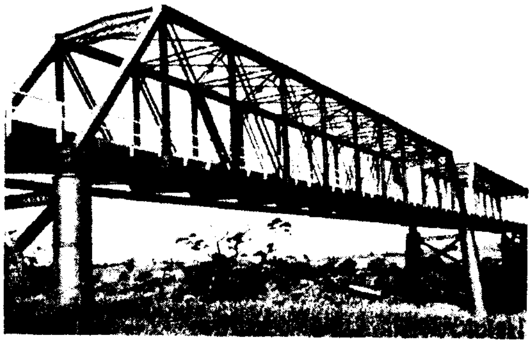


Figure 16 Typical American truss on the North Coast railway (left) and the 1903 Luskintyre road bridge over the Hunter River, Lochinvar.



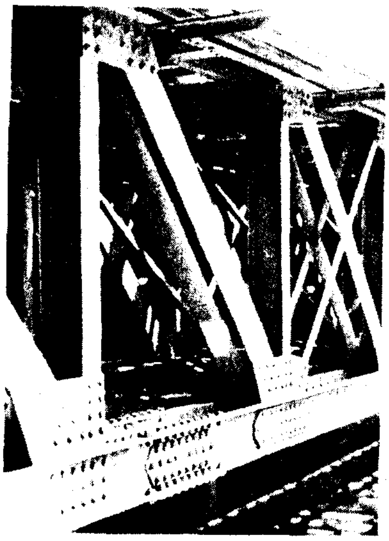


Figure 17 Pairs of flats were used for the tension diagonals in the early Pratt trusses. By 1910 , the North Coast designs had built-up sections and this became standard.

Figure 18 Makers plate on the 1907 railway trusses over the Nepean River , Penrith.

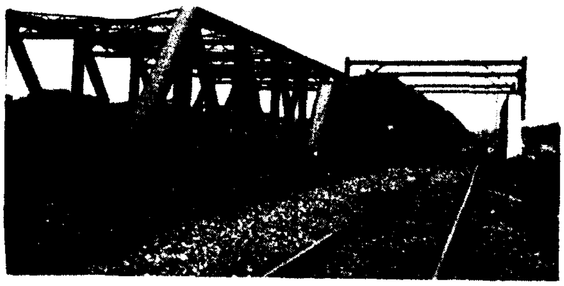


Figure 19 The 1912 through truss (left) and the 1898 pony truss (right) over Ironbark Creek, west of Newcastle.

Figure 20 All the spans of the 1882 Iron Cove Bridge have been relocated in the Jemalong Shire. Function and history continue, albeit at a new location.

4 CONCLUSION

The history of the first sixty years of metal bridges in New South Wales had two distinct phases, the British period from 1863 to 1892, and the American period thereafter. The principal type of bridge was different in each period, the shallow girder in the former and the tall truss in the latter. There were advantages and disadvantages with each type so that by 1900 , engineers had decided on the most suitable application for each. Girders, mainly in the form of plate-web girders, were adequate up to spans of around 30m (100 feet), whereas trusses were the more economical and structurally efficient bridge for longer spans.

The longevity of metal bridges is such that a very large proportion of them from the period under review are extant, and most are still in service. Only a few have been demolished. Consequently, there is a large body of hard evidence of our bridge engineering heritage that is, as yet, not under threat. However , the engineering profession and the public should not be complacent because, the demands upon bridges do change, whereby the owners may judge a bridge to be obsolete and only fit to be replaced and removed , usually scrapped.

Bridges, particularly metal bridges, tend to be durable structures. It is often feasible to give them extended lives once the case for their survival has been vindicated. Figure 20 shows an excellent example of a refurbished recycled bridge, and the disused railway lattice bridge at Como has begun a new and less arduous task of carrying a foot/cycleway across the Georges River.

All bridge replacement proposals should take into account the social, environmental and historical factors about the bridge as well as its function and the relevant technical factors. To that extent, this paper should serve a useful purpose.

5 ACKNOWLEDGEMENTS

This paper is the culmination of nearly five years of research. Although a personal project, its success was made possible by the cooperation of a number of people and organisations. In particular, Brian Pearson, Bridge Engineer, and Bob Mayall , Archivist (DMR), Ross Best, Maintenance Engineer for Bridges and Structures, and John Forsyth, Archivist (SRA), and the staffs of the State and Mitchell Libraries, Sydney.

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D. FRASER

Don Fraser is a Senior Lecturer in Structural Engineering at the University of New South Wales. He began his engineering career with the NSWGR in 1949, graduting from the Sydney Technical College in 1954. Following upon 13 years of practical experience in Sydney and London, he joined the University in 1967 and completed his Pd. D. in 1975.

His technical interests are concrete floor systems, buckling of framed columns and the approximate analysis of structures. He also conducts a course in the History of Civil Engineering. In recent years he has become increasingly invoved with engineering heritage and was Chairman of the National Panel for Engineering Heritage during 1983-84. He was awarded the John Monash Medal for 1985 for his paper "Moveable Span Bridges in New South Wales prior to 1915".